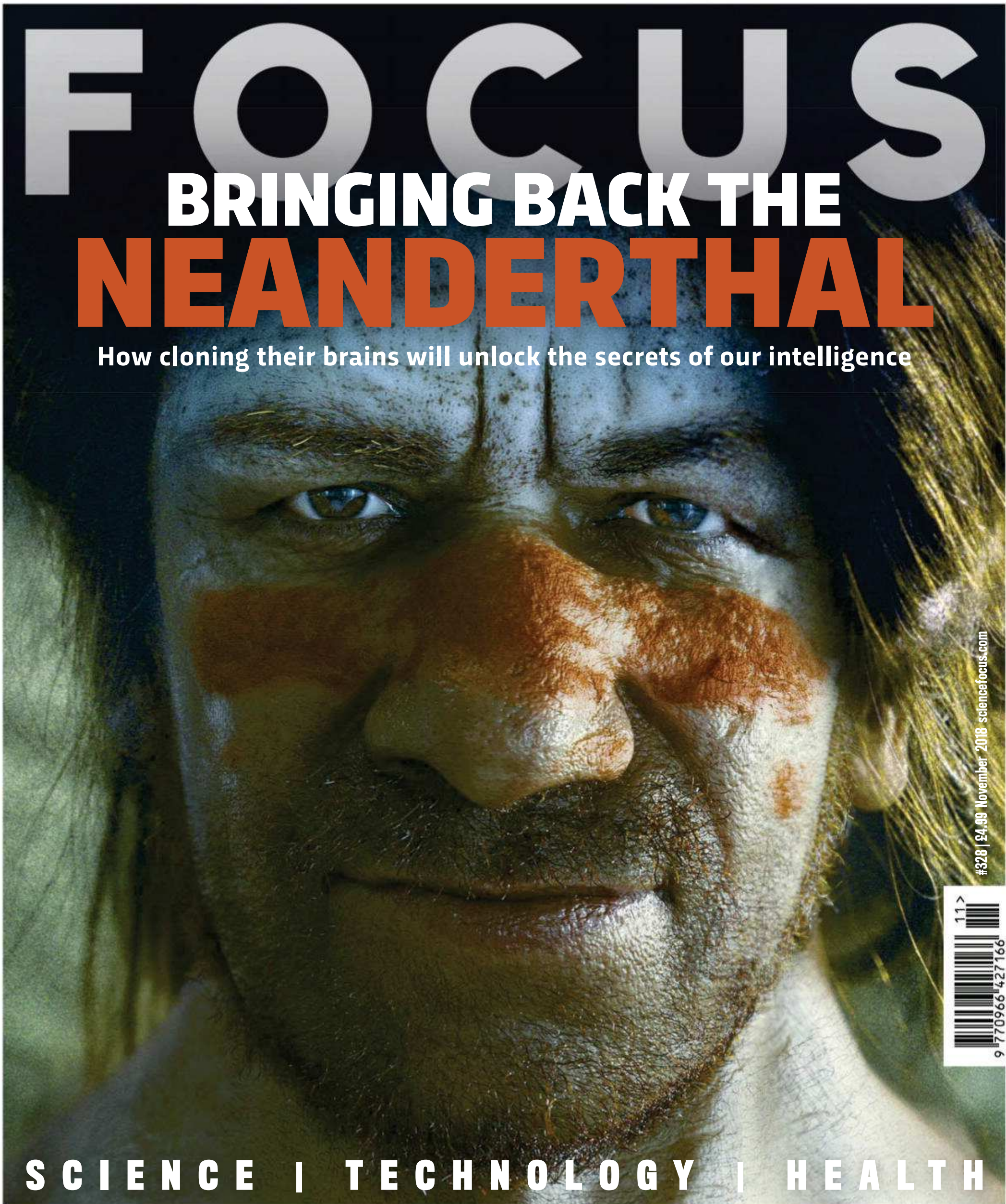


FOCUS

BRINGING BACK THE NEANDERTHAL

How cloning their brains will unlock the secrets of our intelligence



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WELCOME



We know more about the Neanderthal than we do any other human. They're our closest ancient relative after all. Their bones, found across what's now Asia and Europe, whisper that they were fearless hunters who cared for their sick and buried their dead. And the caves in which they were found tell us that they made tools, jewellery and perhaps even art. Thus far, the fossil record suggests that they lived here for some 350,000 years, until

we showed up. More accurately, the Neanderthal story seems to end at about the same time that humans who looked like us left Africa for good and began to spread out across the globe.

Some theories say we wiped our cousins out, others suggest that since Neanderthal DNA resides in most humans today, our ancestors made love, not war, until there were no Neanderthals left. The most likely explanation is that, while we probably fought and fornicated with the Neanderthals, we also out-competed them. At the time of their extinction there were extreme climate fluctuations, and the ecosystems that the Neanderthals depended on rapidly changed. The modern human was better equipped to survive. But why? What made us special? Since we can't go back in time to observe the Neanderthals, scientists are capitalising on a new technique – the creation of mini-brains – to compare our minds with those of our extinct cousins. To find out what gave us the edge turn straight to JV Chamary's brilliant feature on p42.

Daniel Bennett

Daniel Bennett, Editor

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AMY FLEMING

Science journalist Amy looks at the human microbiome and finds out whether the bugs in our bodies are affected by our national diet on p66



ROSIE MALLET

Studying the facial expressions wolves use to communicate may help us understand our dogs. Health writer Rosie finds out more on p54



KATE O'FLAHERTY

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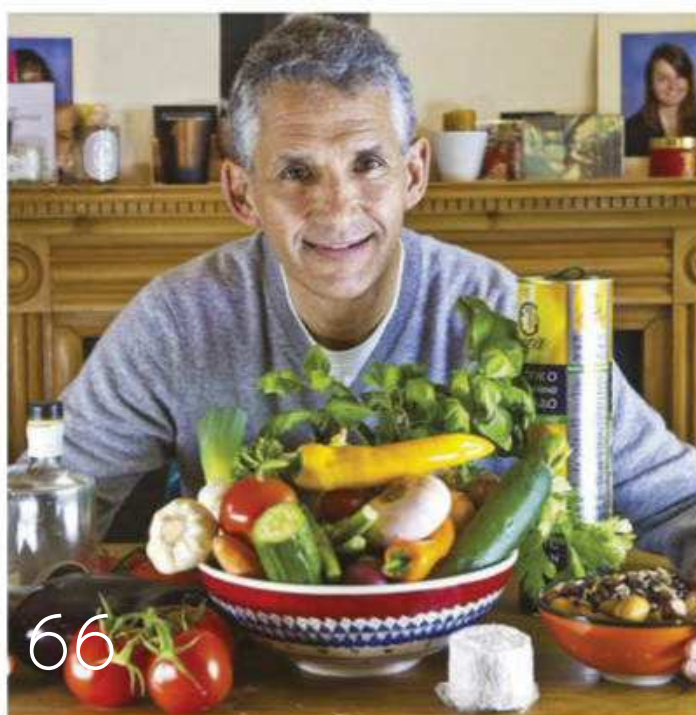
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SPECIAL ISSUE



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Alien encounter

FALSE BAY, SOUTH AFRICA

These two otherworldly creatures are predator and prey. On the left: the blue sea slug. On the right: the deadly tentacle of the Indo-Pacific Portuguese man o' war.

Both were washed ashore as part of a mass stranding of man o' wars in South Africa. The Indo-Pacific Portuguese man o' war is a ruthless killer, using its single, long tentacle to stun and capture its prey. But the sea slug is more than a match. Not only does this tiny (3cm-long) nudibranch feed on man o' wars, but it also steals their poison. The sea slug is immune to the man o' wars stinging cells (nematocysts), so it consumes them and stores them in the tips of its impressive tendrils, or 'cerata', where they help to defend against other foes.

The sea slug is also very well camouflaged. Its blue side faces upwards, blending in with the ocean when seen by seabirds from above, while its silvery-grey side faces downwards, helping it to merge with the ocean surface when the slug is seen from below.

TONY WU/NATUREPL.COM

Sun-kissed

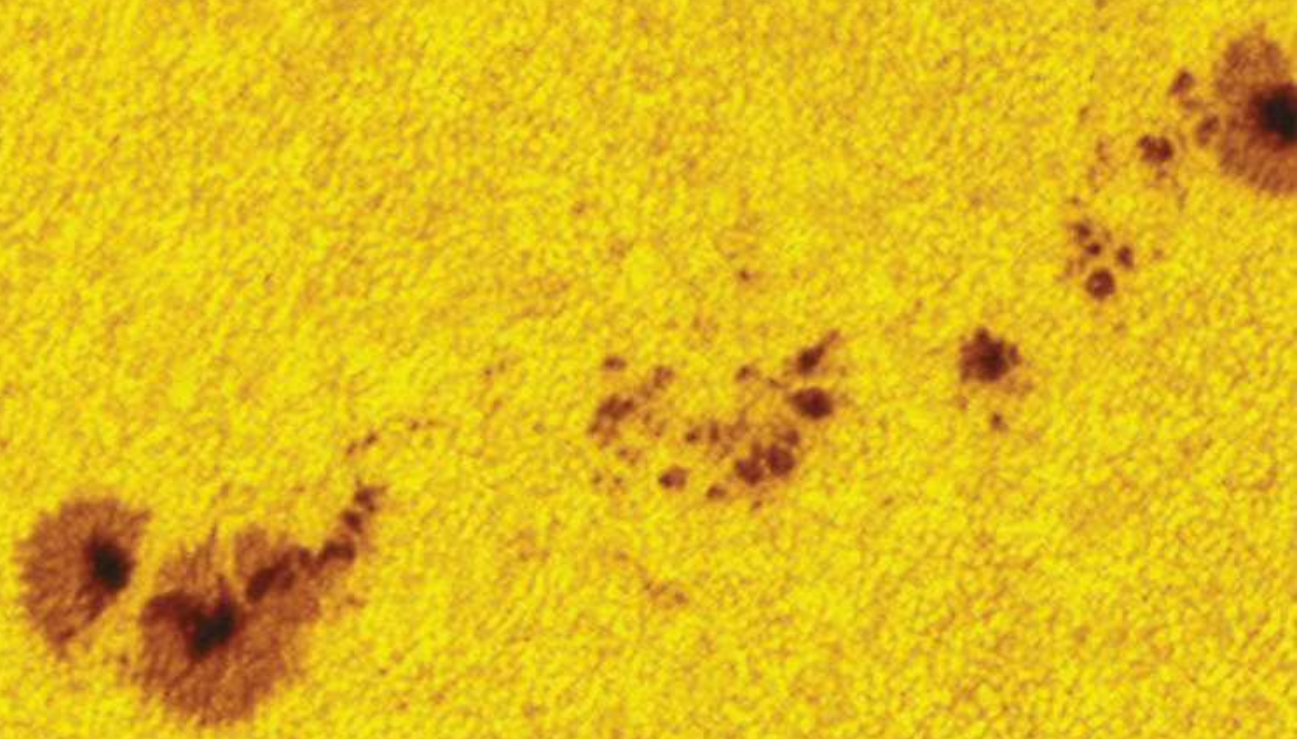
THE SUN, MILKY WAY

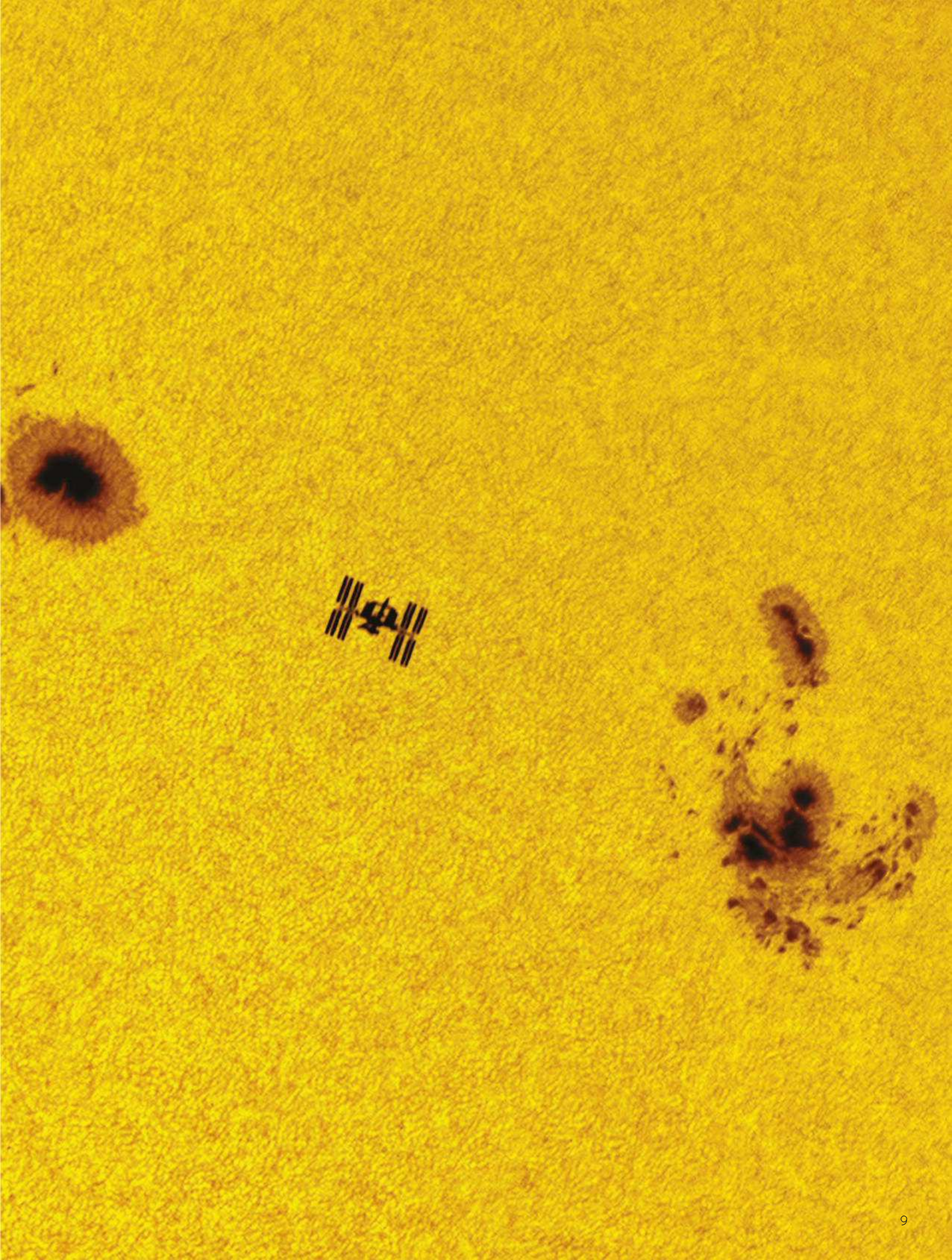
Gliding between two enormous sunspots, the International Space Station looks little more than a toy.

The ISS passed across the face of the Sun on 5 September 2017, captured here by Dani Caxete in Madrid. ISS transits aren't as rare an occurrence as you might think (you can find out the next one near you on transit-finder.com), but the photographer – shortlisted in the Insight Investment Astronomy Photographer of the Year 2018 – had to be quick: the ISS took less than a second to whizz across the solar disc.

The sunspot regions on either side of the ISS – called AR 12674 (on the left) and AR 12673 (on the right) – flared up in September 2017, and are each composed of around 30 individual spots. Sunspots are cooler regions on the Sun's surface that form where the Sun's magnetic field is particularly strong, which inhibits the convection of heat to the surface. The two outbreaks shown here each cover an area of over two billion square kilometres – that's four times the surface area of the Earth.

DANI CAXETE / INSIGHT ASTRONOMY
PHOTOGRAPHER OF THE YEAR 2018





REPLY

Your opinions on science, technology and *BBC Focus*

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MESSAGE OF THE MONTH

Less focus on looks, please

I enjoyed Aleks Krotoski's new column in the October issue (327). But it's not only social media that is to blame for the lack of self-esteem among women. I've long been infuriated by the way that almost every actress playing a role on TV has to be 'physically perfect' (unless, of course, they're playing someone stupid or nasty or a servant, for example). Even if the programme is about a real-life woman from history, you can be sure that the actress playing her will be stunning, no matter what the real woman actually looked like.

If you look at male actors, however, there's a whole different attitude. There are weird-looking, old, wrinkly and sometimes downright ugly men in all sorts of roles in films and on TV, and quite often they are the ones who 'get the girl' (who is inevitably young and beautiful, of course).

To see what I mean you need look no further than the latest reincarnation of *Doctor Who*. The men who have starred in the title role have been of all ages and were not all conventionally attractive. But, you've guessed it, the new female Doctor is young and as near perfect as you can get. What a surprise.

It's no wonder so many women have such low self-esteem. I look forward to the day when women aren't valued only for their looks but I have a feeling I'm in for a long wait.

Elizabeth Wallace, Bognor Regis

I think, sadly, you may be right. There's certainly more progress to be made in terms of on-screen diversity but the first female Doctor is a step in the right direction, at the very least.

– Daniel Bennett, editor

WRITE IN AND WIN!

The writer of next issue's *Message Of The Month* wins a **3Doodler** 3D printing pen. Draw decorations, jewellery, toys or models and watch your drawings leap off the page to become real, tangible objects. A wide range of kits, stencils and plastic 'inks' are available to bring your sketches to life

the3doodler.com



Jodie Whittaker (centre) will emerge from the TARDIS to become the first female Doctor this autumn

The times they are a-changin'

Following your interesting article about science and women (327), you may like to know about our new university in Hereford. It's called the New Model in Engineering & Technology (NMiTE) and will employ a radical approach to technical education. We are committed to an equal gender ratio and to help achieve this we are not insisting on the standard STEM A levels. We believe that anyone with appropriate academic ability, grit, passion and determination can become an engineer with the right training.

We have conducted extensive research in schools to determine what inhibits pupils,

particularly girls, from becoming engineers. When we asked female pupils what sprang to mind for the word "engineer", the typical reply was, "male, overalls, greasy and usually under a car or piece of machinery". You are correct in saying that there needs to be a total mindset change at the pre-GCSE stage in schools.

NMiTE is supported by the University of

Warwick, which is expected to award our degrees until we receive a Royal Charter. Tuition will be in small groups working on practical, employer-led projects. There will

be no formal lectures, but faculty will instruct students in the application of theory to actual real-life issues.



The 46-week term will enable students to obtain a Master's degree in three years.

Our first design cohort of 25 students is already hard at work, under a provost and initial faculty. A further 50 will join next October and in 2020 the first full intake of 300 will start.

This is the first wholly new university in the UK in over 40 years and we hope it will transform engineering education.

Rod Barker, Founder Trustee NMITe, via email

➔ Interesting concept. We'll have to keep an eye on your progress!

– **Daniel Bennett, editor**

In a fog

Micheal Mosley's column on vaping (issue 327, p30) says that vaping is less harmful than cigarettes. But that's not the same as being harmless. When smokers congregate around the entrances to shopping centres or doorways, I hate having to make my way through the cloud of smoke as I suffer with asthma. But what harm does the vape from e-cigs do to my health? Does it have the similar dangers to secondhand smoke?

Oddy Barber, via email

Could there be unexpected dangers lurking in the billowing clouds spilling out of vapers' e-cigarettes?

➔ One small scale study of e-cigarettes use in closed spaces found that secondhand vapour does leave harmful chemicals lingering in the air. That said, it is preferable to the equivalent smoke from a cigarette.

– **Daniel Bennett, editor**

Armageddon outta here

In the August issue (325) I read about the exciting and potentially life-saving NASA and JAXA missions for the OSIRIS-Rex and Hayabusa2 space probes. But the possibility of mining asteroids gave me pause for thought. Is it possible that the change in composition and mass of the asteroid could affect its trajectory and bring about the very disaster we are hoping to avoid – namely a direct collision with Earth?

Jude Pountney, via email

➔ It's theoretically possible, but practically speaking, the distances involved are so incredibly vast that the change in mass needed to alter the asteroid's orbit significantly would need to be impossibly huge. And the odds of 'getting it right', so to speak, by accident are astronomical (no pun intended). If you wanted to do it on purpose, however, that's a different story...

– **Daniel Bennett, editor**



BBC FOCUS

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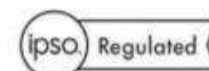
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ADVERTISEMENT FEATURE

DISCOVER NEW WORLDS (FOR REAL)

Find out how an online gaming community is helping to advance science and identify new exoplanets through Project Discovery

EVE
ONLINE

If you're a gamer and science buff, you've probably heard of EVE Online. For the rest of us, it's a Massively Multiplayer Online platform that lets players explore space, discovering uncharted territory and solving complex problems and challenges - with a few battles along the way. Since its launch in 2003, EVE Online has amassed a huge and loyal following.

Massively Multiplayer Online Science (MMOS), a new innovative citizen science platform connecting scientific research and video games, spotted the potential of harnessing all this people power. And so, in collaboration with the astronomy department of the University of Geneva, and of course the spaceship pilots of EVE Online, Project Discovery was born.

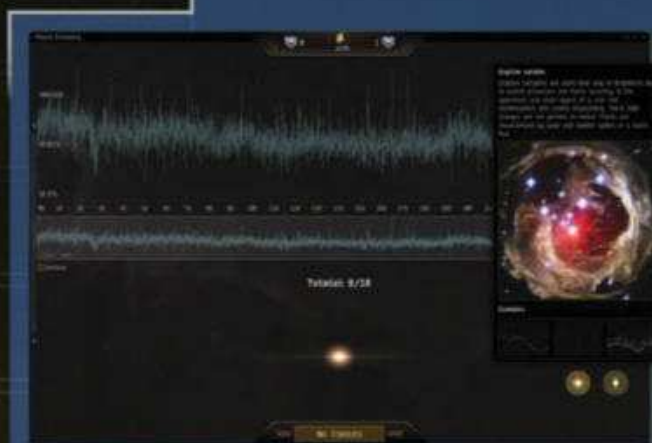


Project Discovery
In-game rewards



»» OUT OF THIS WORLD ««

In **Project Discovery**, players are tasked with **analysing** real-world astronomical data, helping to **identify** previously undiscovered planets outside of our solar system - and there are countless ones out there. One of the most promising methods of finding them is known as transit photometry. It involves **measuring** the light coming from a star and making **use of the fact** that a planet eclipsing the star **will reduce** the amount of light that we can observe.



These **measurements** of light are presented as graphs, called **light curves**, and show the **luminosity** of a star. By **finding** places where the curve dips regularly, players can **identify** possible new worlds. The information **gathered** is monitored by a team of astronomers at Geneva University, led by Professor Michel Mayor. When a **consensus** has been reached, they'll confirm whether the players have identified a new world.

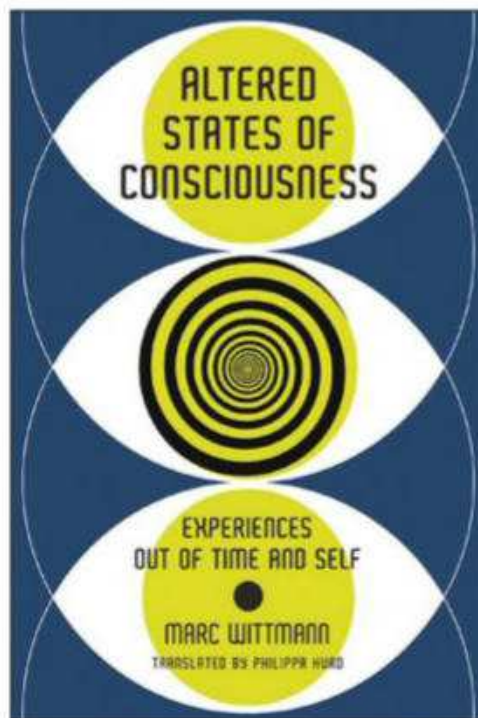
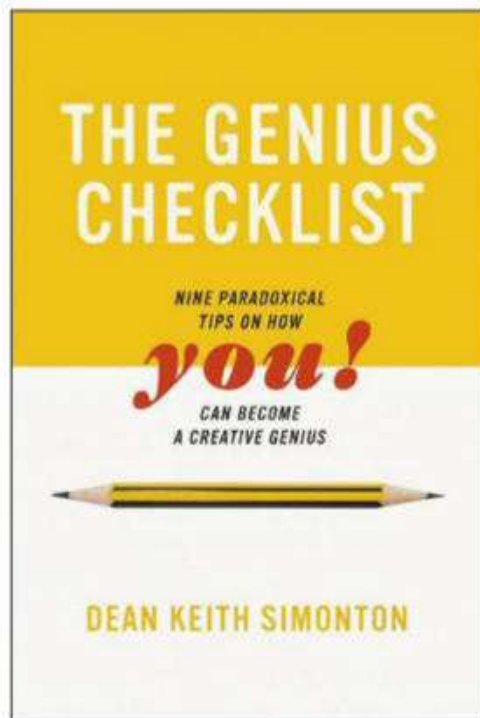
Project Discovery is a perfect fit with EVE Online as players are already exploring the galaxy of New Eden. Anyone can get involved, from any point in the game - and so far over 66 million submissions have been sent through for analysis. A scientist from Geneva University commented: "Although we are well aware of the EVE community's tendency to surpass expectations, we may yet again have underestimated the capsuleers' capacity for science."

The **hope now** is that more and more developers will consider integrating citizen science into their computer games so that even more gamers can play their part in uncovering the mysteries of the universe.



“Wherever you are in EVE Online, you're one click away from advancing real science in Project Discovery, a unique mini-game that's quick, easy and rewarding to play”

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Fall Books On The Cutting Edge

New Titles from
MIT Press

The Genius Checklist

Nine Paradoxical Tips on How You Can Become a Creative Genius

By **Dean Keith Simonton**

What it takes to be a genius: nine essential and contradictory ingredients.

The Tales Teeth Tell

Development, Evolution, Behavior

By **Tanya M. Smith**

What teeth can tell us about human evolution, development, and behavior.

Twitterbots

Making Machines That Make Meaning

By **Tony Veale and Mike Cook**

The world of Twitterbots, from botdom's greatest hits to bot construction to the place of the bot in the social media universe.

Altered States of Consciousness

Experiences Out of Time and Self

By **Marc Wittmann**

What altered states of consciousness — the dissolution of feelings of time and self — can tell us about the mystery of consciousness.

How Smart Machines Think

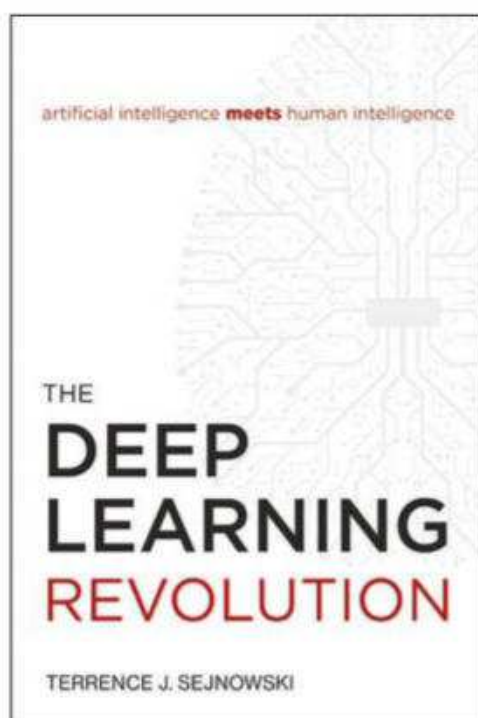
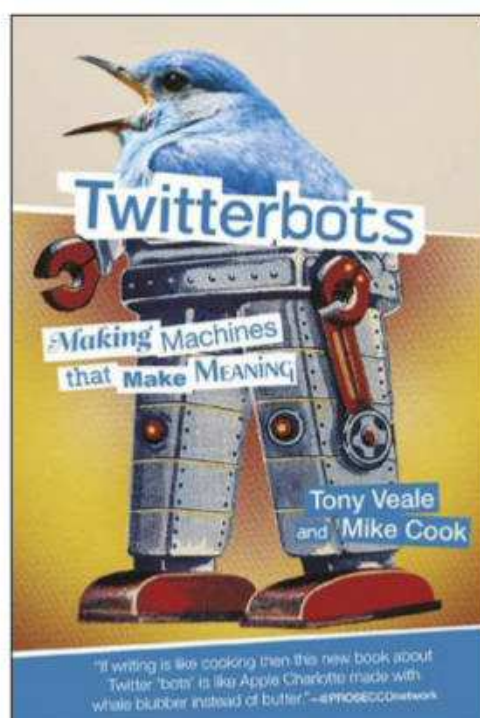
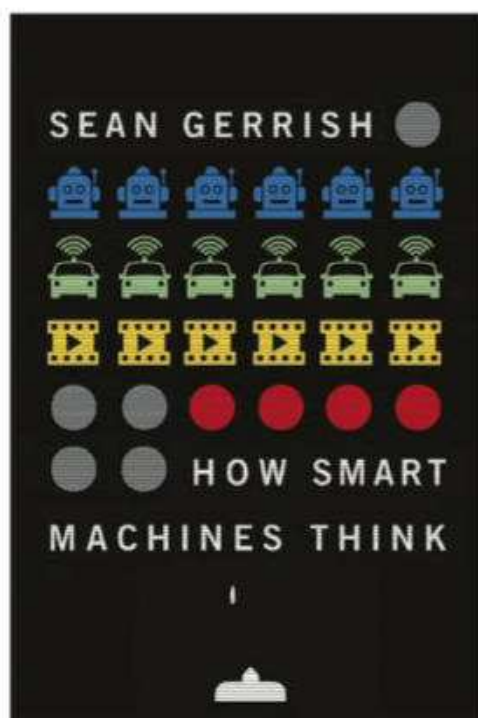
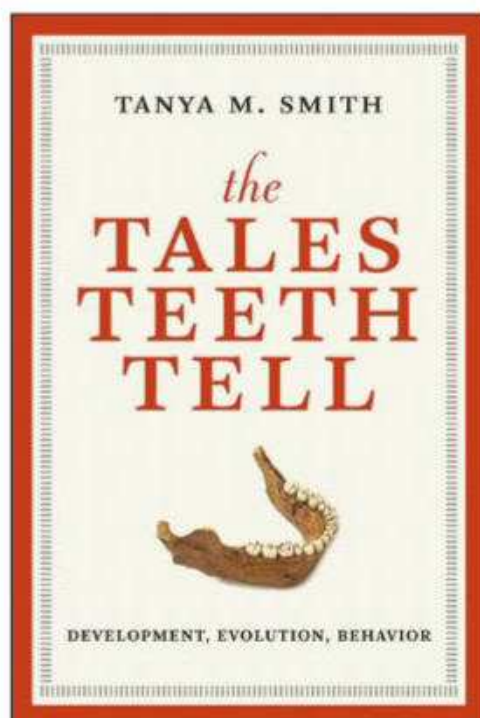
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By **Terrence J. Sejnowski**

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DISCOVERIES

DISPATCHES FROM THE CUTTING EDGE

NOVEMBER 2018

EDITED BY JASON GOODYER



MEDICINE

IMPLANTS HELP PARALYSED PATIENTS WALK AGAIN

A groundbreaking piece of technology is helping victims of severe spinal trauma regain the use of their legs

UNIVERSITY OF LOUISVILLE HOSPITAL

“THE TREATMENT IS BASED ON THE IDEA THAT, IN SPITE OF THE DAMAGE TO THE SPINAL CORD, SOME NERVE CONNECTIONS THAT CROSS THE INJURY SITE REMAIN INTACT. IMPLANTS PLACED BELOW THE INJURY SITE SEND PULSES OF ELECTRICITY THROUGH THE AREA EXCITING THE NERVES IN THE SPINAL CORD”

Four patients with severe spinal cord injuries can walk again thanks to a new technique that combines electrically stimulating implants and physical therapy, which has been developed by researchers at the University of Louisville.

Of the four patients in the study, all were able to stand independently and two were able to walk with the assistance of walking aids such as walker frames or horizontal balance poles despite being injured more than two years ago.

“This research demonstrates that some brain-to-spine connectivity may be restored years after a spinal cord injury as these participants living with complete motor paralysis were able to walk, stand, regain trunk mobility and recover a number of motor functions without physical assistance when using the epidural stimulator and maintaining focus to take steps,” said Prof Susan Harkema, associate director of the Kentucky Spinal Cord Injury Research Center. “We must expand this research – hopefully, with improved stimulator technology – to more participants to realise the full potential of the progress we’re seeing in the lab, as the potential this provides for the 1.2 million people living with paralysis from a spinal cord injury is tremendous.”

The treatment is based on the idea that, in spite of the damage to the spinal cord, some nerve connections that cross the injury site remain intact. Implants placed below the injury site send pulses of electricity through the area exciting the nerves in the spinal cord. It’s thought that this kickstarts the system: the activity gives the spinal cord, which has been isolated from the brain by the injury, the sensitivity it needs to hear signals from the brain again. This gives the legs a chance to

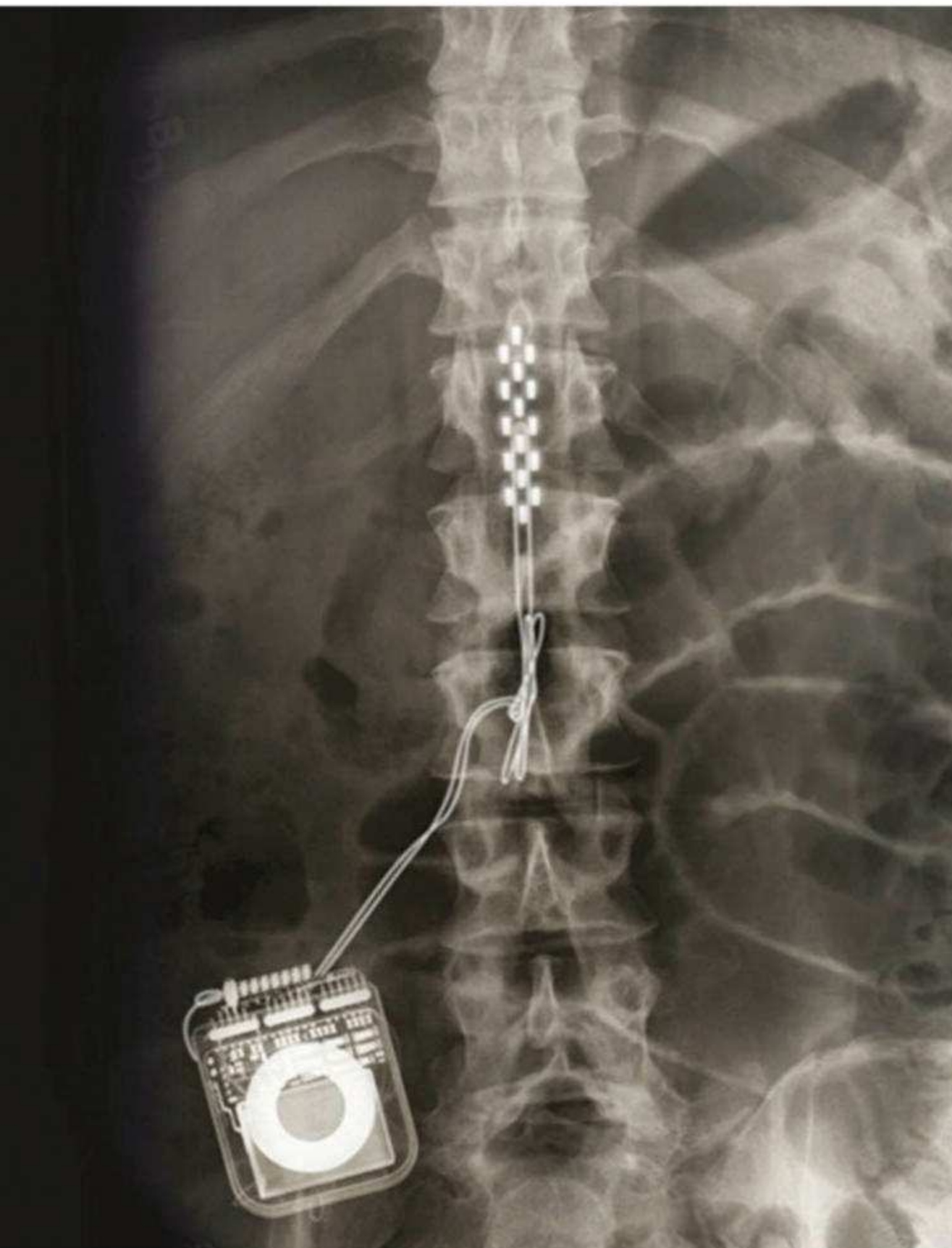


ABOVE: (From left) Dr Claudia Angeli, Jeff Marquis and Prof Susan Harkema at the Kentucky Spinal Cord Injury Research Center

reconnect with the brain and slowly relearn the distinct nerve activation patterns that result in walking via the locomotor training. In a session, the participants are placed into a harness while specially trained staff move their legs to simulate walking on a treadmill.

That’s the theory, in practice however, the precise healing process isn’t fully understood. “Now I think the real challenge starts, and that’s understanding how this happened, why it happened and which patients will respond,” says Kristin Zhao co-principal investigator the study.

Initially, they were unable to stand, walk or voluntarily move their legs, even after eight to nine



weeks of daily locomotor training. However, once the stimulators were implanted and switched on, all of the participants were able to stand and two of them were able to walk using mobility aids.

“We are seeing increasing interest in the use of technologies such as epidural stimulation in the treatment of spinal cord injury and restoration of locomotor, cardiovascular and urodynamic functions [bladder control],” said Maxwell Boakye, clinical director of the Kentucky Spinal Cord Injury Research Center. “Epidural stimulation is likely to become a standard treatment with several improvements in design of the device to target more specific neurological circuits.”

ABOVE: An X-ray of the epidural implant that provides electrical stimulation to patients with spinal cord injuries

CASE STUDIES

Jeff Marquis

35, Louisville

Following a nasty crash while out riding his mountain bike with a roommate in Montana in 2011, Jeff was left paralysed from the chest down as a result of a broken neck. Following treatment with an epidural stimulator and months of intensive rehab he became the first participant in this study to attain bilateral steps.

“The first steps after my mountain biking accident were such a surprise, and I am thrilled to have progressed by continuing to take more steps each day,” he said. “In addition, my endurance has improved, as I’ve regained strength and the independence to do things I used to take for granted, like cooking and cleaning. My main priority is to be a participant in this research and further the findings, as what the University of Louisville team does each day is instrumental for the millions of individuals living with paralysis from a spinal cord injury.”



Kelly Thomas

23, Florida

As a teenager Kelly loved the outdoors and could often be found riding horses, playing soccer or working on the family farm. But in July 2014 a car accident left her paralysed from the waist down and confined to a wheelchair, with doctors saying she would never be able to walk again. Now, following months of epidural stimulation treatment and strenuous rehab, she has proved the doctors wrong by becoming one of the first paraplegics in the world to take steps under her own power.

“Being a participant in this study truly changed my life, as it has provided me with a hope that I didn’t think was possible after my car accident. The first day I took steps on my own was an emotional milestone in my recovery that I’ll never forget, as one minute I was walking with the trainer’s assistance and, while they stopped, I continued walking on my own. It’s amazing what the human body can accomplish with help from research and technology,” she said. “They were helping me as usual and then they stopped and I took maybe three or four steps in sequence. I just stopped and my lips started quivering, my face got hot and my eyes got teary, and I was like, ‘Oh my God! I just took steps!’”



PROSTHETICS

3D PRINTING TECHNOLOGY BRINGS BIONIC EYE ONE STEP CLOSER

A research team at the University of Minnesota has 3D printed an image sensor array onto a hemispherical surface for the first time, taking a big step towards the creation of a bionic eye that could help blind or partially-sighted people see.

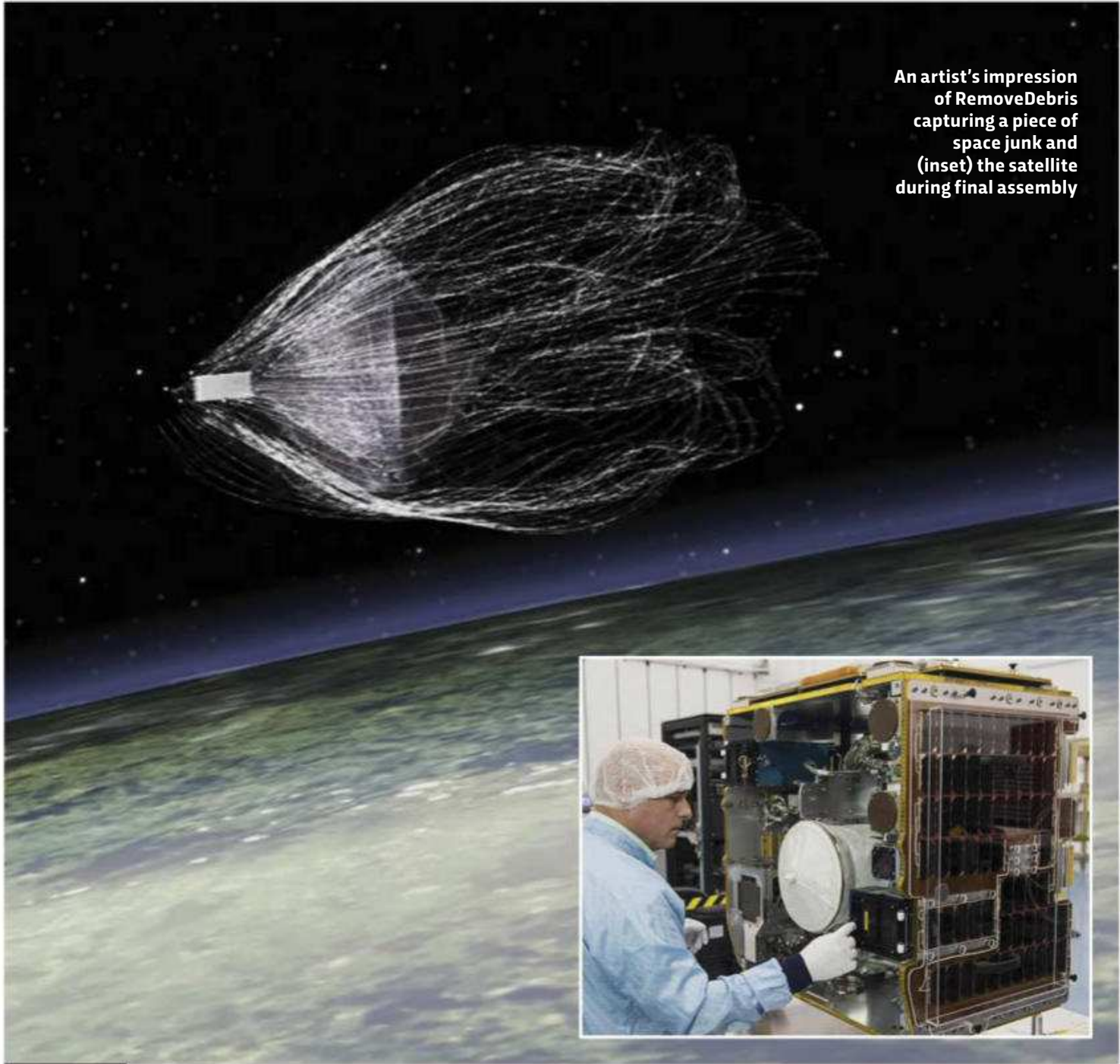
Using a custom-built 3D printer, the team laid down a base layer of silver particles onto the surface of a hemispherical glass dome. The silver particles stayed in place and dried uniformly instead of running down the curved surface. They then used semiconducting polymer materials to print photodiodes (tiny devices that convert light into electricity) on top of the silver base. The resulting prototype 'bionic eye' was able to convert light to electricity with 25 per cent efficiency.

"Bionic eyes are usually thought of as science fiction, but now we are closer than ever [to making them a reality] using a multi-material 3D printer," said Professor Michael McAlpine of the University of Minnesota. "We have a long way to go to routinely print active electronics reliably, but our 3D-printed semiconductors are now starting to show that they could potentially rival the efficiency of semiconducting devices fabricated in microfabrication facilities. Plus, we can easily print a semiconducting device on a curved surface."

The team plans to create a second prototype with more light receptors and develop a method of printing onto a soft hemispherical material that can be implanted into an eye socket.

A new 3D printing technique makes it possible to produce image sensor arrays on hemispherical surfaces





An artist's impression of RemoveDebris capturing a piece of space junk and (inset) the satellite during final assembly

IN NUMBERS

**1,200
TESLAS**

The strength of a record-breaking magnetic field generated by researchers at the University of Tokyo. That's 50 million times as strong as the Earth's magnetic field.

91.2%

The proportion of children in England receiving MMR vaccinations in 2017, according to data from NHS Digital. The World Health Organisation recommends at least 95% to prevent outbreaks.

**10
MINUTES**

Practising mindfulness meditation by simply focussing on the sensation of your breathing for 10 minutes a day can improve concentration and working memory, a study at Osnabrück University, Germany.

SPACE

NET SUCCESSFULLY SNARES SPACE JUNK IN PRACTICE RUN

Back of the net! The Surrey Space Centre's RemoveDebris satellite has successfully captured 'space junk' on its first test run.

The satellite deployed its net to capture a man-made target simulating a piece of space junk while in orbit more than 300km above the surface of the Earth (most real space junk lies between 800-850km above Earth). It is the first demonstration of its kind ever to succeed.

"We are absolutely delighted with the outcome of the net technology," said Professor Guglielmo Aglietti, director of the Surrey Space Centre. "While it might sound like a simple idea, the complexity of using a net in space to capture a piece of debris took years of planning, engineering and coordination between the Surrey Space Centre, Airbus and

our partners – but there is more work to be done. These are very exciting times for us all."

The US Space Surveillance Network currently tracks around 40,000 pieces of space junk orbiting Earth. With some pieces travelling at speeds approaching 48,300km/h (30,000mph) there is a serious risk of them damaging satellites should a collision occur.

In the coming months, RemoveDebris will test more of its junk retrieval technologies including a vision-based navigation system that uses specially designed cameras to analyse and observe potential pieces of junk and a harpoon capture system. Once the trials are complete the satellite will release a drag-sail that will bring it into the Earth's atmosphere where it will burn up.

HEALTH

"Humans can run for long distances at a sustained pace"

Biologists have identified a mutated gene that might explain why humans are so good at endurance running. Prof Ajit Varki of the University of California, San Diego, explains

ABOVE: Kenya's Eliud Kipchoge won September's Berlin Marathon in 2:01:39. The IAAF had yet to ratify his time as this issue went to press but if it does, Kipchoge will have knocked 1:18 off fellow Kenyan Dennis Kimetto's world record (2:02:57) set in 2014

How do humans compare against other animals?

Many animals are capable of short-distance sprints, but few do endurance running, besides horses, wolves and ostriches. None of the other primates run long distances and humans are very unusual in that we can run for very long distances at a sustained pace – if you're in reasonable physical condition.

When did our ancestors gain running ability?

Based primarily on the structure of bones and likely implantation of muscles, the fossil record says it probably began with *Homo erectus*, which eventually gave rise to our lineage. About 2 million years ago, the skeleton changed dramatically: you got a structure that's much like modern humans - the striding, bipedal gait of a healthy young person, which can break into a run.

Which genes influence endurance running?

CMAH is the first known gene that might contribute to endurance running – it's been around for 500 million years and got lost in our ancestors. The gene produces an enzyme that adds an additional oxygen atom to molecules on the cell surface, called sialic acid. Throughout the

body, sialic acid enables cells to interact with one another. We still have the same amount of total sialic acid, but we lost one major form due to a mutation in the CMAH gene about 2-3 million years ago – which coincides with when our ancestors gained the ability to run long distances.

You made mice with human-like mutated genes. How did they run?

There were two tests. One was a stress test: we put normal and mutant mice on treadmills and they ran until they reached exhaustion. The regular mice ran for 25 minutes, whereas the mice with human-like CMAH genes ran for 35 minutes. Importantly those mice had not even been trained, they had been couch potatoes. Then we put running wheels into the cages; mice love to run – they run kilometres at night. Initially there was not much difference, but over 10-15 days, the 'humanised' mice got better. And when we took those trained mice and put them back on the treadmill test, the difference was even more obvious: the mutant mice ran for 60 minutes instead of 40, so around 50 per cent longer. We collaborated with Ellen Breen, who looked at their muscle biologically and showed it had



OPTIMISTS

If you view the glass as half full, read on. Maintaining positive thoughts and feelings can reduce your risk of cardiovascular diseases, researchers at Northwestern University have found. Optimistic people are more likely to take exercise, eat healthily and not smoke or be stressed, they say.

HAY FEVER SUFFERERS

Say goodbye to summers spent with itchy eyes and a streaming nose. A team at the University of Copenhagen have developed a vaccine using sugar molecules that prevents the development of the allergy in mice.

GOOD MONTH

BAD MONTH

MAKEUP WEARERS

Women who wear heavy makeup are falsely perceived as signalling a greater interest in casual sex by both men and women, researchers at Gettysburg College have found.

AUTHORITARIAN BOSSES

A study at Binghamton University has found bosses who assert absolute control with little consideration of the well-being of their employees have a negative effect on the performance of their workforce.



BELOW: Humans are unique among primates for our endurance running capability, and scientists believe they've identified the gene that explains why

decreased fatigue, improved oxygen utilisation and some other factors.

What does your study reveal about humans?

Of course, mice don't have many other features that humans have, such as our upright posture and ability to sweat. But if we can understand the difference between the two kinds of mice in more physiological-, molecular-level detail, that may be relevant to athletic training. Evolution gave humans this benefit of being able to do sustained exercise. It's clearly part of our genetic heritage. The irony is that this CMAH gene mutation may have made us more prone to certain diseases, such as diabetes and cardiovascular disease. But if you just did your exercise regularly, especially endurance exercise, you would benefit.



DIGESTED READ

A genetic mutation that is thought to have cropped up in early humans between 2-3 million years ago could be what kick-started the changes that enabled us to sustain the effort required to run long distances. When scientist spliced the gene into mice, the rodents became able to run significantly longer than their 'normal' counterparts.

THEY DID WHAT?!



MONKEYS TAUGHT TO GAMBLE

What did they do?

Researchers at Johns Hopkins University trained a pair of rhesus macaques to gamble against a computer in order to win drinks of water. They were allowed to choose between two machines: one set up with 20 per cent chance to win 10ml and one set up with an 80 per cent chance to win 3ml.

What did they find?

Both monkeys consistently chose the machine with the greater pay off despite the longer odds. Even when they were no longer thirsty they still went for the riskier bets, seemingly egged on by the excitement of a big win. However, when the team suppressed a region of the monkeys' brains known as the supplementary eye field they were 40 per cent less likely to take risky bets.

Why did they do that?

As non-human primates and humans share a similar brain structure, the researchers believe the findings should apply to also people and could potentially lead to treatments for compulsive gamblers.

ZOOLOGY

FIRST EVER OMNIVOROUS SHARKS IDENTIFIED

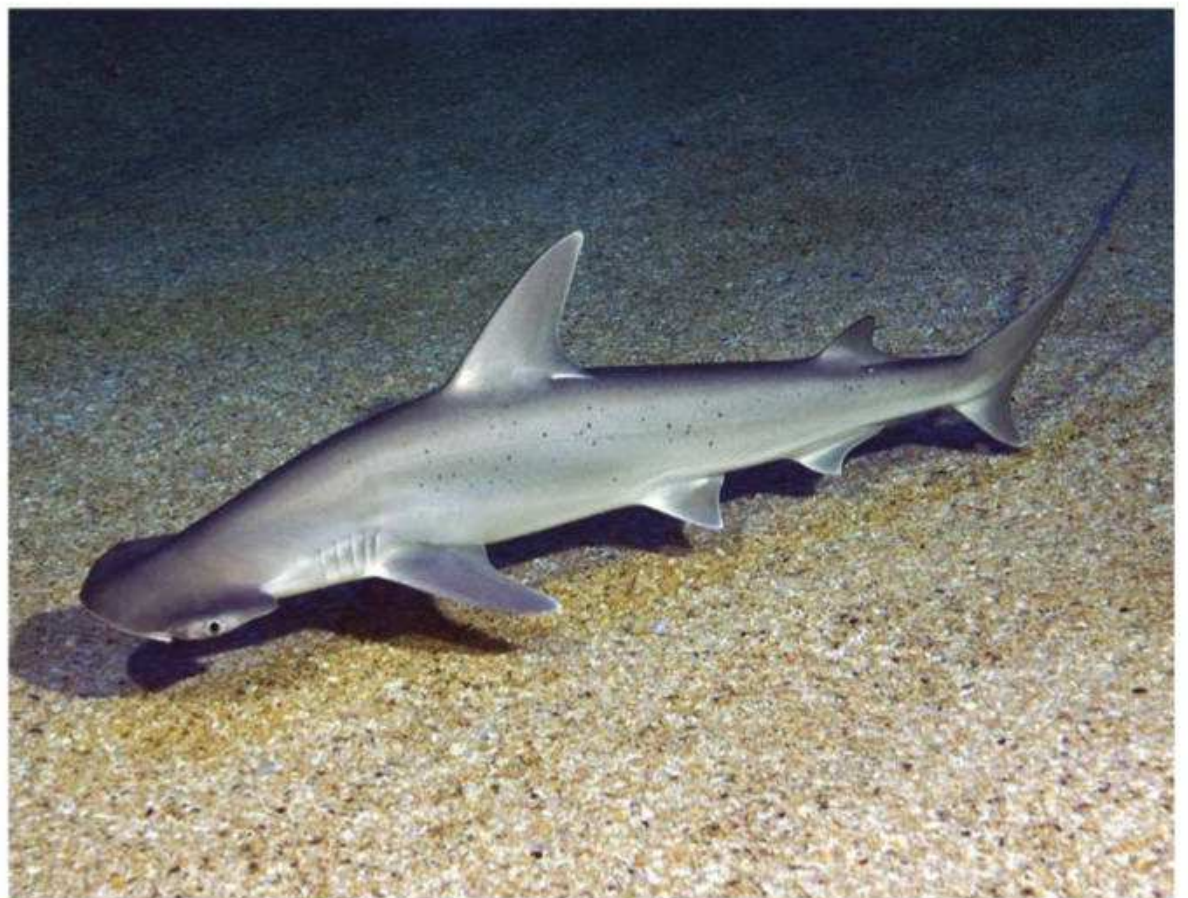
We're going to need a bigger salad cart. Researchers at the University of California have found that bonnethead sharks, smaller cousins of the more famous hammerheads, supplement their diet of crabs, shrimp and squid with mouthfuls of seagrass. It is the first time sharks have ever been confirmed to be omnivorous, they say.

Traces of seagrass have often been found in the guts of bonnethead sharks but it was assumed that they were consuming it unintentionally rather than seeking it out. To test this the team grew seagrass in water laced with powdered sodium bicarbonate. As the seagrass grew it absorbed a distinctive form of carbon into its structure that the team were able to detect the

presence of in the sharks livers, plasma and red blood cells.

They then fed five captive sharks a diet consisting of 90 per cent of the modified seagrass and ten per cent squid for three weeks. All of the sharks gained weight during this time. The resulting analysis of the sharks revealed that not only were the sharks deliberately consuming the seagrass but that they were also able to break it down and absorb nutrients from it. It turns out that bonnetheads have special enzymes in their stomach acids that allow them to breakdown the cellulose found in the plant material. They were able to digest 45 per cent of the organic matter found in the seagrass putting them on a par with juvenile green sea turtles.

Bonnethead sharks get the nutrition they require through a diet of vegetation and meat





The L13 fragment features intersecting red lines and was found in South Africa's Blombos Cave (inset)



ARCHAEOLOGY

OLDEST KNOWN DRAWING FOUND IN SOUTH AFRICAN ROCK

Here's the work of a really old master. An international team of researchers have found what they believe to be the oldest known example of a drawing – a series of crosshatched lines sketched onto a fragment of rock with a red ochre crayon 73,000 years ago.

Dubbed L13, the fragment was found among a number of stone tools, perforated shells and other material collected from the Blombos Cave in South Africa in 2011, a hollowing nestled inside a cliff face overlooking the Indian Ocean. It is believed that the cave was used as a resting place by early human hunters. Around 70,000 years ago the cave was sealed off by sand leaving the artefacts inside protected from the elements and well preserved.

After several years of microscopic and chemical analysis, along with experimental recreations of the pattern using various techniques, the team determined that the lines were drawn with a pointed ochre crayon and that the surface was first smoothed down by rubbing. The pattern is the earliest known drawing, preceding the oldest previously discovered works by at least 30,000 years, the researchers say.

It's unclear what the symbol meant, if anything, to those who drew it. But there is other evidence that the first *Homo sapiens* in this region of Africa used different techniques to produce similar signs on different materials, which supports the theory that these markings served a symbolic function.

TRENDING

Your guide to the hottest topics in the world right now

#ADDICTION

ANCIENT ILLNESSES STILL CAUSING PROBLEMS

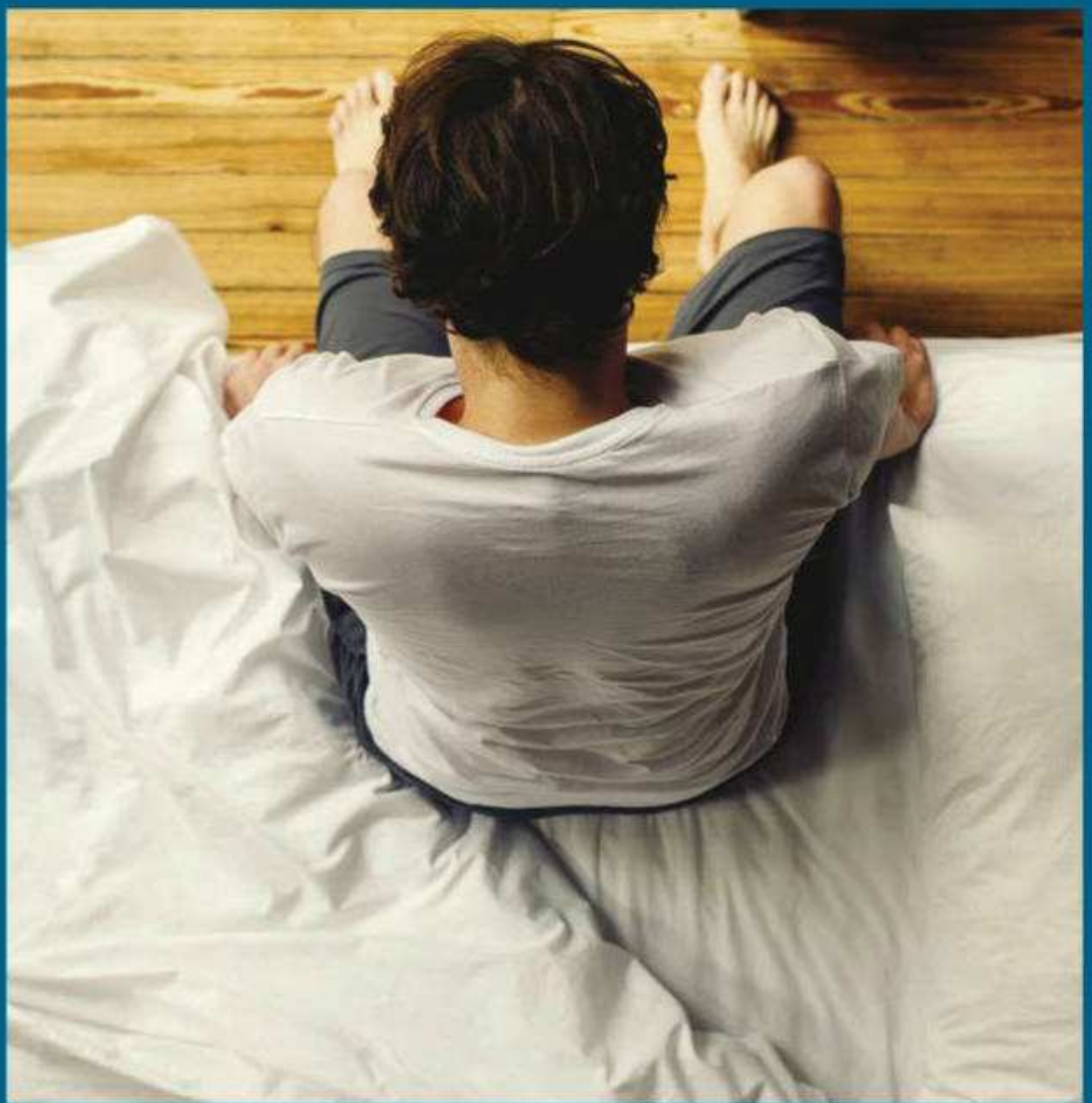
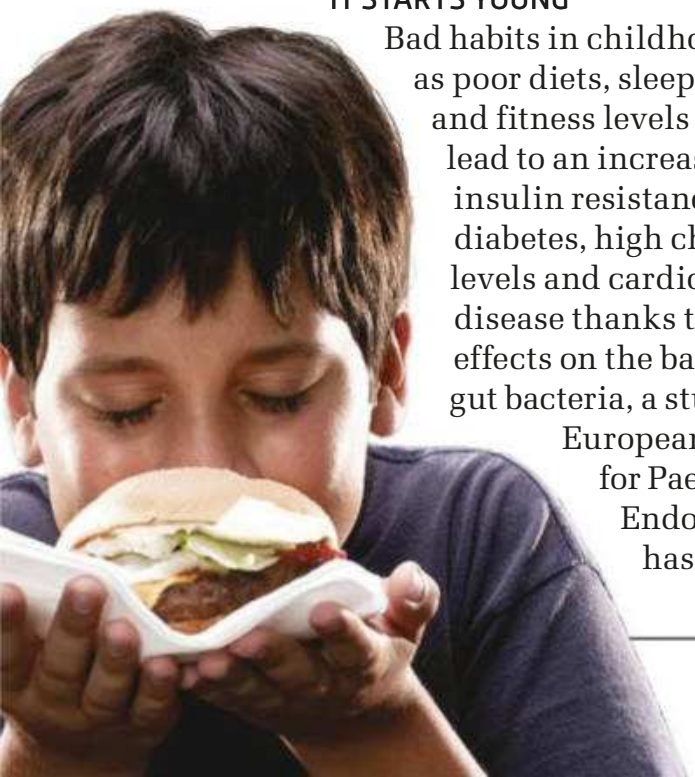
Our genome is littered with remnants of ancient retrovirus infections that afflicted our ancestors. Now, researchers at the University of Oxford have found that one such virus, HK2, is frequently found in those with drug addictions and other substance abuse problems. HK2 lies close to a gene involved in the regulation of dopamine and reward processing.



#MICROBIOME

IT STARTS YOUNG

Bad habits in childhood such as poor diets, sleeping habits and fitness levels could lead to an increased risk of insulin resistance, type-2 diabetes, high cholesterol levels and cardiovascular disease thanks to their effects on the balance of gut bacteria, a study at the European Society for Paediatric Endocrinology has found.



#SLEEP

EVERY SNOOZE COUNTS

Losing a single night's sleep could affect the liver's ability to process glucose and process insulin, potentially adding to the risk of metabolic diseases such as type 2 diabetes and fatty liver disease, a study in sleep-deprived mice carried out at Toho University in Japan has found.

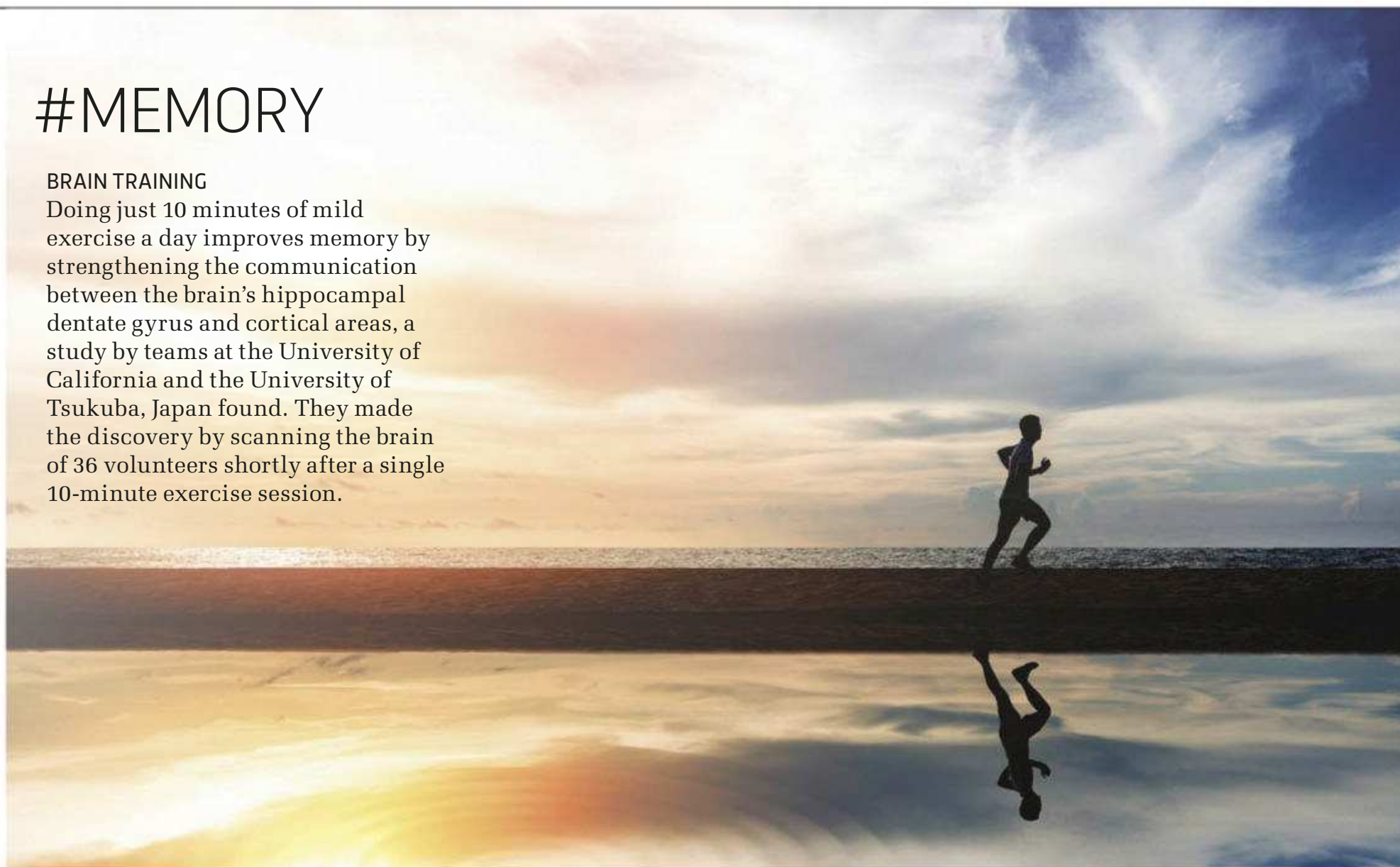
DREAM GENES

Researchers at the University of Tokyo have identified two genes that may regulate how much we dream. When researchers 'turned off' the genes in mice using genetic editing tool CRISPR the mice almost entirely stopped experiencing REM sleep – the period of sleep in mammals and birds that's accompanied by rapid movements of the eyes and the tendency to dream vividly.

#MEMORY

BRAIN TRAINING

Doing just 10 minutes of mild exercise a day improves memory by strengthening the communication between the brain's hippocampal dentate gyrus and cortical areas, a study by teams at the University of California and the University of Tsukuba, Japan found. They made the discovery by scanning the brain of 36 volunteers shortly after a single 10-minute exercise session.



#PLASTIC

PLASTIC POLLUTION SPREADS FURTHER

Tiny particles of plastic that have leached into water supplies are being gobbled up by mosquito larvae and subsequently being consumed by birds, a study carried out at the University of Reading has found. The finding means that microplastics in the water could spread to pollute new environments and food chains thanks to the feeding habits of birds, bats and other insect eating animals, the researchers say.

TURNING LANDFILL TO LANDFUEL

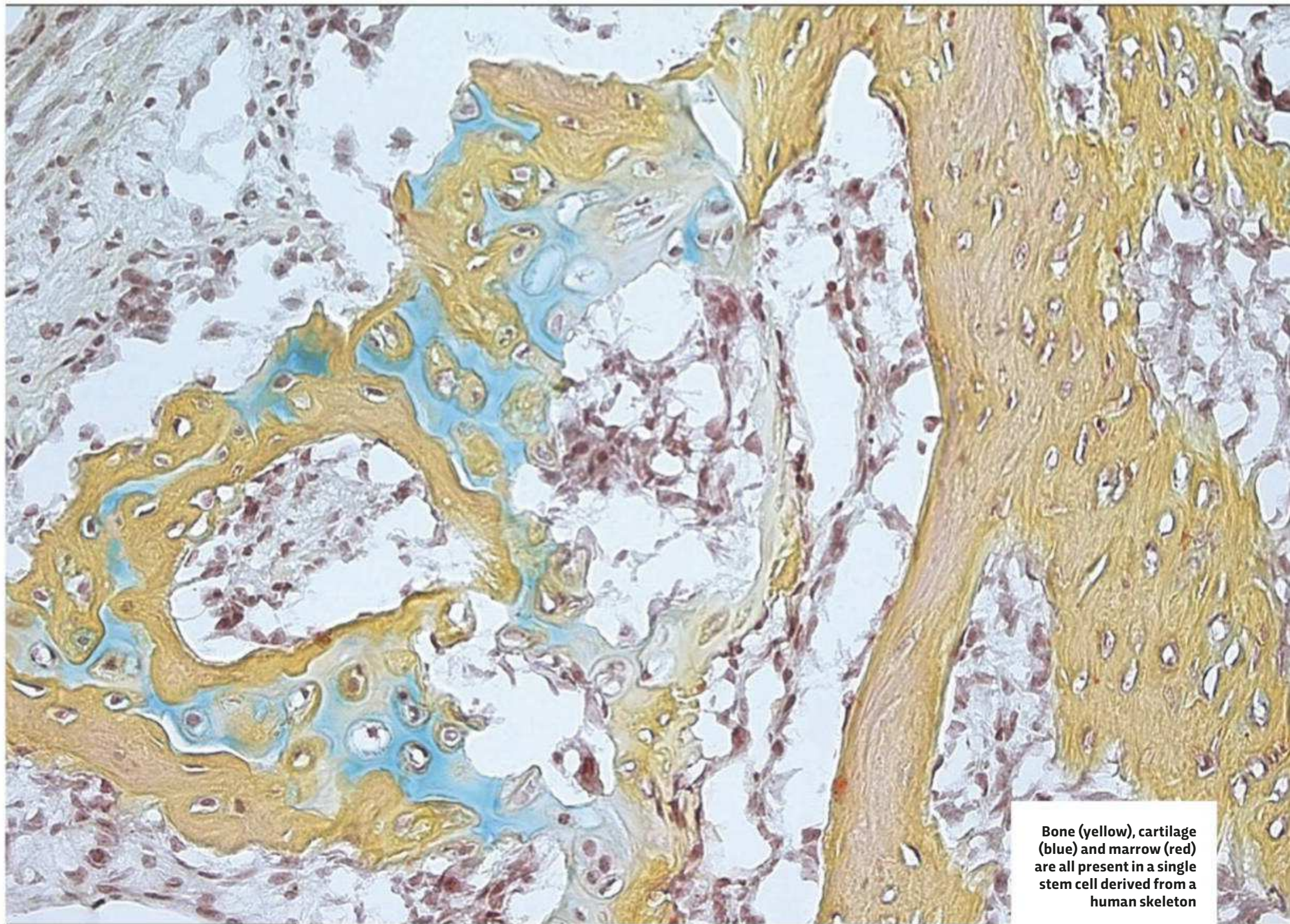
Researchers at Cranfield University have developed a method of recovering valuable chemicals from discarded plastics that could potentially be used to produce liquid fuels. The team are currently working on refining a complex heat treatment process known as pyrolysis in which high temperatures are used to break plastics down into reusable elements.

#DEPRESSION

CALCULATING YOUR MOOD

Researchers at MIT have created a neural network model that can look for signs of depression in recorded human speech and text. They formed the model by feeding sequences of text and speech into the network and allowing it to 'learn' the tell-tale signs that a person was depressed. In subsequent tests the model successfully picked out depressed people with 77 per cent accuracy.





Bone (yellow), cartilage (blue) and marrow (red) are all present in a single stem cell derived from a human skeleton

STEM CELL RESEARCH

NEWLY IDENTIFIED STEM CELLS COULD REGROW BONES

Here's something worth boning up on: researchers at Stanford University have identified and produced skeletal stem cells from human induced pluripotent stem cells – those that can grow into nearly all kinds of cells in the body – for the first time. The discovery could lead to treatments for a range of degenerative bone disorders or even enable us to grow new bones for reconstructive surgery following trauma, according to the team at Stanford.

Following on from work identifying skeletal stem cells in mice published three years ago, the Stanford team tracked down similar cells that are able to grow into bone and cartilage in human bone marrow. The team then went on to develop a method of growing these skeletal stem cells from induced human pluripotent stem cells.

“IT MAY BE POSSIBLE TO UNCOVER THE MECHANISMS THAT UNDERLIE TISSUE GROWTH AND REGENERATION”

The team now plans to investigate the differing regenerative properties of different species of vertebrate with an end goal of developing treatments for a broad spectrum of health conditions ranging from age-related diseases such as osteoporosis and osteoarthritis to non-healing skeletal injury, blood disorders and even cancer.

“By comparing the molecular and functional differences in specific types of stem cells between different species of vertebrates, it may be possible to uncover the mechanisms that underlie tissue growth and regeneration, and apply this understanding towards enhancing health and rejuvenation in humans,” said Charles Chan of the Stanford University School of Medicine.

CHAN AND LONGAKER ET AL, TOM KLEINDINST

NEUROSCIENCE

OCTOPUSES HIGH ON MDMA BECOME TOUCHY-FEELY

If ASBOs were given out to sea creatures, it's highly likely octopuses would get slapped with more than their fair share. They spend much of their lives alone, frequently get into fights and have even been known to attack and kill one another after mating. Now, a study at Johns Hopkins University has found that giving them a small dose of MDMA – a psychoactive drug also known as ecstasy – makes them so sociable that they touch and hug one another.

The findings suggest there could be an evolutionary link between the social behaviours of the sea creatures and humans despite the species being separated by 500 million years on the evolutionary tree, the researchers say.

"The brains of octopuses are more similar to those of snails than humans, but our studies add to evidence that they can exhibit some of the same behaviours that we can," said assistant professor Gül Dölen, at Johns Hopkins University School of Medicine. "What our studies suggest is that certain brain chemicals, or neurotransmitters, that send

signals between neurons required for these social behaviours are evolutionarily conserved."

The team placed four California two-spot octopuses that had been exposed to MDMA, one at a time, into a set-up of three connected water

chambers: one empty, one with a plastic action figure under a cage and one with a female or male laboratory-bred octopus under a cage. All four tended to spend more time in the chamber where the octopus was caged. Under normal conditions, without MDMA, the octopuses avoided the male caged octopuses.

"It's not just quantitatively more time, but qualitative. The octopuses tended to hug the cage and also put their mouth parts on the cage," said Dölen. "This is very similar to how humans react to

MDMA; they touch each other frequently."

However, the team at Johns Hopkins University School of Medicine cautions that the results are preliminary and need to be replicated before octopuses might be used as models for brain research.

WARNING

Ecstasy (MDMA) is a Class A drug according to UK law.

Anyone caught in possession of it will face up to seven years in prison, an unlimited fine, or both.

More information and support for those affected by substance abuse problems can be found at bit.ly/drug_support



The drug ecstasy appears to have a similar effect on octopuses' brains as it does on humans'

THINGS WE LEARNT THIS MONTH

MOST OF THE HUMAN GENOME ISN'T BEING STUDIED

Researchers at Northwestern University in the US have found that scientific studies are neglecting up to 80 per cent of genes in the human genome. The effect is thought to be due to the ease of justifying the future studies of genes that are already well known, they say.

THE IMPACT OF WWII BOMBING RAIDS WERE FELT AT THE EDGE OF SPACE

Using daily records collected by the Radio Research Centre in Slough between 1943 and 1945 a team at the University of Reading has found bombing raids by the Allies during WWII produced shockwaves big enough to weaken the electrified upper atmosphere – the ionosphere – above the UK, 1,000km away.

REGULAR BEDTIMES CAN LEAD TO BETTER HEALTH

A study of nearly 2,000 adults carried out at Duke University has found that keeping regular hours can help to reduce the likelihood of a person developing heart disease, diabetes and obesity.

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It may sound technical and complicated, but putting it into practice is easy. Once you've plugged in the first adapter, all other adapters that are plugged in within the next two minutes are automatically and securely connected to each other. There is also the new Home Network app of devolo available, in case there are questions, which offers a step-by-step installation guide.

devolo Magic is available online from the end of October. There are a variety of packages to choose from, from Starter Kits and single adapters to Whole-Home-WiFi-Kits for larger homes. devolo provides a three-year manufacturer's warranty for all products.

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'WOKE HORROR' OPENS OUR MINDS



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Aleks Krotoski is a social psychologist, broadcaster and journalist. She presents BBC Radio 4's *Digital Human*.

Now is the time of year when the nights draw in. And with the longer nights come darker thoughts full of monsters and ghouls, along with cautionary tales of things that go bump. In the past, horror poked at psychological terrors. Since the internet, though, the latest ghouls are more socially conscious. Let's take a look at woke horror.

A poster child for the woke horror genre is the Academy Award-winning *Get Out*. It was released in 2017, the year that, arguably, liberals 'woke up' from their filter bubbles and got political. In *Get Out*, Chris, who is black, is invited to meet his girlfriend's liberal upstate New York white family. But the sociopolitical commentary comes from the creepy way that Chris knows exactly what's about to happen based on a lifetime of the racist microaggressions that he's experienced in US society.

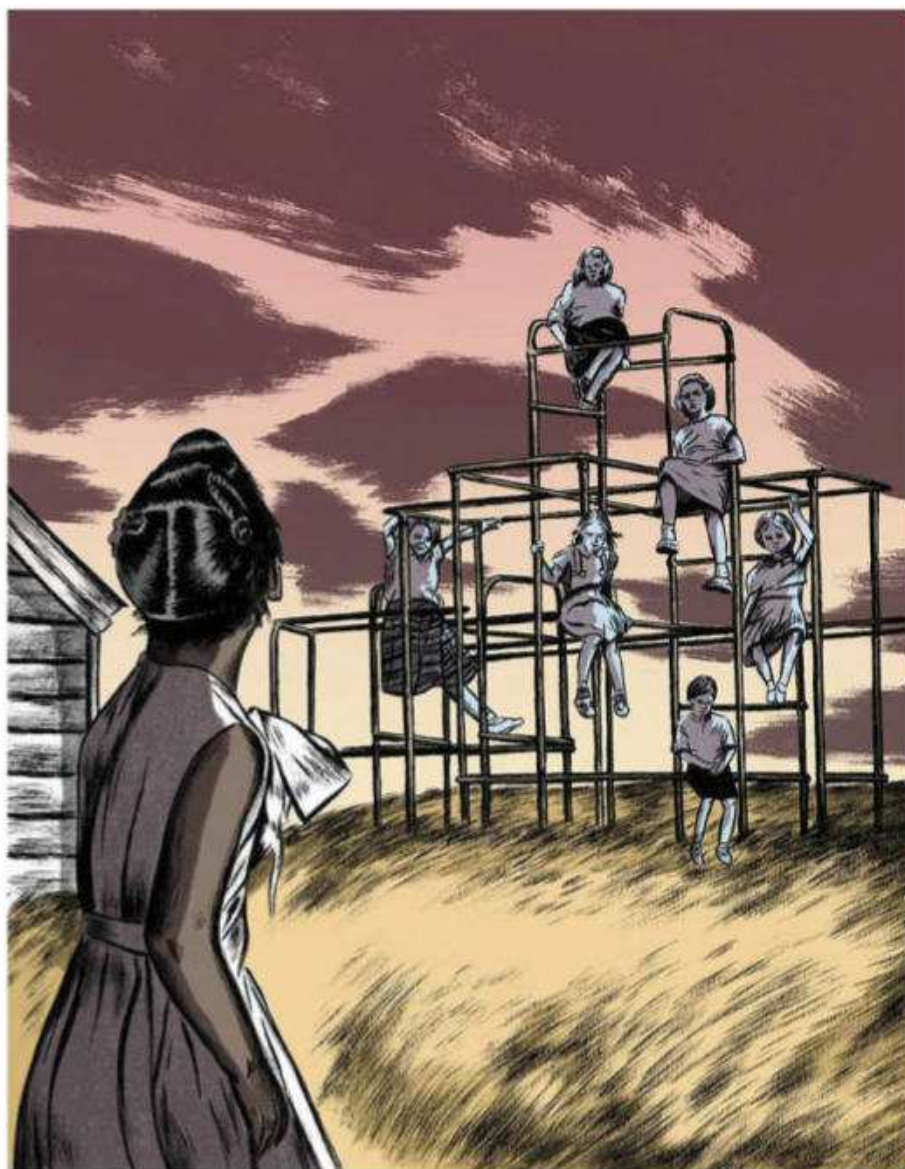
Woke horror is gaining power among the increasingly diverse talent that's flooding into Hollywood. They're using the mass platform to let audience members of all backgrounds know what it feels like to be an Other. These aren't just token black-guy-gets-killed-first trope characters either. The horror medium is being re-imagined to scare the pants off people in a more meaningful way, and to get them to walk in someone else's shoes.

Psychologists and social workers have long used role play to create empathy. More recently, researchers are using it to target some of the subtle things that we do and say that contribute to someone else's unknown distress – those microaggressions that stem from baked-in stereotyping and cultural indoctrination. The aim is to help society, not the individual, though it works at both levels. A lifetime of feeling put-upon can lead to problems with mental health, from anxiety and depression to binge drinking and poor academic performance. These, of course, can then contribute to systemic problems that keep particular groups of people down.

"WELL-MEANING PEOPLE MAY NOT EVEN REALISE THEY'RE BEING OFFENSIVE"

Earlier this year, Dr Christy M Byrd from the University of California, Santa Cruz, published a framework on the best way to respond to prejudiced comments. Her paper, *Microaggressions Self-Defense: A Role-Playing Workshop For Responding To Microaggressions*, tries to embed a way for both sides to act that is effective, rather than pushing the aggressor and victim into even more polarised camps. Because the thing is, well-meaning people may not even realise they're being offensive. She argues against confrontation, and for ego management. Saying things like, "I thought you were an open-minded person" and "What did you mean by that?" opens up the conversation, rather than shutting it down. And if a face-to-face situation doesn't do the job, you can always role play in computer games. In a recent study published in *Social Science*, Lars de Wildt and Stef Aupers interviewed 20 international gamers from diverse religious backgrounds to find out how playing a character of a different religion affected their worldviews. They found that playing these characters let them empathise with the Other, and suspend their own worldviews. So atheists saw the logic in religious inclinations, and Christians, Hindus and Muslims were able to see the similarities in their faiths.

The modern demon of our darkest thoughts is still the Other, but the trend is to wake people up to their unconscious actions and beliefs by giving them another person's shoes and therefore interrupt social polarisation. If this happens to cover the walls with fake blood, I'm glad. As long as it scares the Dickens out of me. **F**



PORTRAIT: KATE COPELAND ILLUSTRATION: JOE GOUGH

IMPROVE YOUR MOOD IN WINTER



Michael Mosley is a science writer and broadcaster, who presents *Trust Me, I'm A Doctor* on BBC Two. His latest book is *The Clever Guts Diet* (£8.99, Short Books).

This is a miserable time of year. The days are getting shorter, colder and damper and there is still a long way to go until Christmas.

A study published a couple of years ago in the journal *Epidemiology* showed striking evidence that early winter casts a malign shadow. By inspecting hospital records between 1995 and 2012, Danish researchers discovered that the number of people diagnosed with moderate to severe depression jumps by 11 per cent every November.

One of the researchers, Dr Søren Dinesen Østergaard, told me this increase is too large and consistent to be a coincidence. He also thinks it is linked to the fact that Danish clocks go back an hour at the end of October, as they do in the UK. So in his view this November surge is likely to be psychological rather than physical.

I think he may be onto something, but I also think there are physiological reasons why we get gloomier in winter. A couple of years ago I was diagnosed with seasonal affective disorder (SAD). I get more gloomy and introspective as the winter wears on. I also become more stressed and anxious. I sleep badly, find it harder to get motivated and I develop a craving for sugary carbs.

I'm not bad enough to need antidepressants or psychotherapy, but last year I bought a light box, which now sits beside my computer, bathing me in 10,000 lux of bright white light for an hour or so each day. I also take the dog on early walks since exercise outdoors in the morning light seems to be particularly effective at reducing the impact of SAD. And it seems to be working.

If you suffer from winter gloom, as well getting more light you could try changing what you eat. In an Australian study called Smiles (Supporting the Modification of lifestyle in Lowered Emotional States) 67 patients with moderate or severe depression, most of whom were on medication or having psychotherapy, were

“EXERCISE OUTDOORS SEEMS TO BE PARTICULARLY EFFECTIVE”



randomly allocated to either a Mediterranean-style diet (less sweets and fast food; more fruit and veg, and red wine rather than beer or spirits) or 'social support'. After 12 weeks 32 per cent of those on the Med diet went into remission compared with eight per cent in the control group. Those who stuck closest to the Mediterranean diet enjoyed the biggest improvement in mood.

Other mood enhancers we have tested on my BBC series, *Trust Me, I'm A Doctor*, include yoga, gardening or mindfulness. Last year we ran an eight-week experiment with Prof Angela Clow of Westminster University, in which we recruited 68 volunteers and split them into four groups. One group was asked to join Green Gym, a charity that encourages people to plant trees, sow meadows and establish wildlife ponds. A second group was sent to a weekly yoga class, while a third was prescribed a daily dose of mindfulness. We also had a control group, who were asked to continue as normal.

Clow and her team asked the volunteers to fill in questionnaires before and after, and also measured their levels of the stress hormone cortisol. At the end of eight weeks, the gardening and the yoga groups had both improved compared with the controls, although mindfulness came out on top. What I found interesting was the wide range of responses. Although some people got a lot of benefit from these interventions, others got none. It turned out that the best predictor of whether you would benefit or not was whether you enjoyed it. And on that note, I'm off to walk my dog again. **F**

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to the Tsars', and the other from South Africa's Western Cape. Australia comes up trumps with Andrew's Shiraz, full of fine spicy, brambly fruit. California's calling card is Zinfandel and Gold Star is our buyer's pick of the bunch thanks to its massive 15% vol. and soft berry, black pepper character.

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drinkaware.co.uk

INNOVATIONS

PREPARE YOURSELF FOR TOMORROW

NOVEMBER 2018

EDITED BY HELEN GLENNY



IFA 2018 REPORT

We went to Berlin to get a preview of some of the tech and gadgets being showcased at Europe's biggest consumer electronics fair

LG CLOi SUITBOT

LG threw its hat in the human-enhancement ring at IFA 2018, unveiling the CLOi SuitBot, a robotic exoskeleton designed to support walking, standing and working. It was made in collaboration with start-up SG ROBOTICS and has AI technology so it can learn about the user's physical capabilities, environment and movements, then use that information to suggest optimal movements and stances to maximise efficiency.

ETBC, lg.com



8K TVs: MORE PIXELS THAN YOU NEED?

This year's resolution will get sharper so screens can become even bigger

What is 8K?

It's a measure of screen resolution; 8K images are roughly 8,000 pixels wide. TVs with 8K screens have around 33 million pixels in total – four times that of 4K TVs – to offer a super-clear, lifelike picture.

Do we need all those pixels?

That depends. You probably won't notice the difference in a TV that's 65 inches or smaller, but upwards of that, screen size is limited by resolution. 8K allows you to go really big; a lot of the 8K TVs introduced at IFA were over 80 inches. Then there's the issue of 8K content. Some Hollywood productions have started using 8K cameras, and the 2020 Olympics will be broadcast in 8K, but only in Japan. The move to 8K seems inevitable, but it'll take some time.

When can I buy one?

8K TVs have actually been on sale for a while. Sharp sells an 70-inch model for just over £10,000. But given that so many were presented at IFA, we expect to see more models trickling into stores by the end of this year.



SAMSUNG Q900R 8K QLED TV

Samsung announced 65, 75, 82 and 88-inch versions of its top of the line 8K TV. Each of the models include AI upscaling, which enhances non-8K content so you get a visual benefit even if you're stuck watching shows in HD or 4K while the world catches up.

£TBC, [samsung.com](https://www.samsung.com)



LG 88-INCH OLED TV

Instead of QLEDs, LG's huge 8K masterpiece is made with OLEDs, which are better at producing blacks for improved picture quality. Some question how well OLEDs work with 8K, but LG's TV looked great under showroom conditions at IFA.

£TBC, [lg.com](https://www.lg.com)



SHARP AX1 LED

Sharp was the only brand to debut a second-generation 8K TV at IFA: the AX1. It will go on sale in Europe in early 2019 and be available in 60, 70 and 80-inch versions all with 8K upscaling and an 8K picture slide show mode.

£TBC, [sharp-world.com](https://www.sharp-world.com)

WATCH OUT

Spurred on by upgrades for Google's Wear OS and the prospect of new Apple timepiece, smartwatch manufacturers pulled out all the stops at IFA.



CASIO PRO TREK WSD-F30

This new rugged smartwatch from Casio has GPS navigation and lets you store five coloured maps offline to keep you on track when you're navigating in the wild. Setting it to run in 'Extend Mode' switches the display from colour to monochrome in order to boost the battery life from one to three days for extended expeditions into the wilderness.

ETBC, casio.co.uk



SKAGEN FALSTER 2

Skagen's first Falster was one of the sleekest smartwatches on the market, and its second-generation version packs features into that same minimalist design. The Falster 2 uses Google's Wear OS and has added a heart rate monitor, GPS, and waterproofing, as well as Google Pay, which means you'll be able to use it to buy tickets on public transport in some cities.

From £269, skagen.com



DIESEL ON FULL GUARD 2.5

Diesel's made some big updates to its massive On Full Guard. Like the Skagen, it has a new heart rate sensor, GPS technology, water resistance to 30m and Google Pay. Though its battery only lasts for two days, fast-charging technology will make it easy to top up.

ETBC, uk.diesel.com



SONY FES WATCH U

If you're looking for a watch with a bit of flamboyance, consider Sony's FES Watch U. It has e-ink displays on its face and strap, so you can customise them based on your outfit. It comes with 12 designs preloaded but you can download more from selected artists and create your own.

From £529, sony.co.uk

SMART SOUNDS

Whether it’s adding voice control, waterproofing or adaptable noise-cancelling, speakers and headphones are being loaded with ever more tech. Here are five of the highest-tech tune pumps



HARMON-KARDON CITATION SERIES

Harmon-Kardon’s well known for delivering high-quality audio, but its new multi-room tabletop Citation range adds serious usability to sleek design. The introduction of Google Assistant voice control means you can change from pop to jazz while your hands are covered in cake batter, and built-in Chromecast makes streaming simple. The speakers are cloaked in dirt- and flame-retardant wool fabric from Kvadrat, an acoustics textiles specialist.

From £179.99, harmankardon.co.uk

2



ULTIMATE EARS MEGABOOM 3

Ultimate Ears announced the latest updates to its MegaBoom series at IFA. The MegaBoom 3 has a new “magic button”, a single button that can play, pause and skip, as well as connect to your phone and start streaming music. The MegaBoom 3 is also primed for outdoor use, being both waterproof and dustproof, and it floats, so you can take it swimming.

From £169.99, ultimateears.com

3



BANG & OLUFSEN BEOSOUND EDGE

The Beosound Edge is a monolithic speaker – 50.2cm in diameter – that can stand on your floor or hang on a wall. If it’s on the floor, you can adjust the volume by rolling the speaker back and forth. It also has an ‘active bass port’, which opens and closes to produce the most suitable sound for the particular volume.

Approx. £3,000, bang-olufsen.com

4



JBL EVEREST 710GA GOOGLE ASSISTANT HEADPHONES

JBL’s new line of on-the-ear headphones adds Google Assistant, so you don’t need to whip out your phone to get directions. Just hold your finger on a sensor on the left earpiece and ask Google whatever you want to know. The headphones also have ShareMe 2.0 connectivity so you can share your music with anyone nearby via Bluetooth (say hello to DIY silent discos) and an echo-cancelling mic to make call audio crystal clear.

Approx £230, uk.jbl.com

5



SONY WH-1000XM3

This year, a ton of new headsets featured adaptable noise-cancelling, where you can turn the silencing facility up or down depending on your activity. Sony’s new on-the-ear model has a three-way switch so you can flick between no noise cancelling, ambient noise cancelling and a full noise cancelling setting, which blocks out everything but your tunes. The sound quality is brilliant and the headband has been slimmed down from the previous model.

£300, sony.co.uk

THE BEST OF THE REST

These gadgets don't fit in any defined categories, except one: things we're putting on our Christmas list.

LENOVO YOGA BOOK C390

The dual-screen Yoga Book C390 is a laptop, tablet and e-reader all rolled into one. Its colour LCD screen is paired to an e-ink display that can serve as a sketchpad when it's not displaying a keyboard that gives haptic feedback when you type. It also has a 'knock-knock' feature lets you open it by rapping your knuckles on the device.

£TBC, lenovo.com



LG STYLER

This high-tech wardrobe is far from a robot version of Tan from *Queer Eye*, but it does shake the wrinkles and odours out of your clothes while gently steaming and drying them. You can control it using either an app or your voice.

Approx. £1,525, lg.com

LAIKA CAMTOY

This high-tech dog toy lets you interact with your pup while you're in the office. You can talk to your pooch through the toy or even get face-to-face time using a webcam, and if your dog behaves itself you can make Laika release a treat. It also has an autonomous mode, just in case you actually need to work.

Approx. £250, adoptlaika.com



SOMNOX SLEEP ROBOT

Having trouble sleeping? Hug this bean-shaped, robotic cushion and it pulses gently, imitating deep breathing at a frequency that'll send you off to sleep. It also plays soft music or ambient sounds, like falling rain or a cat purring.

£499, meetsomnox.com



The Somnox pulses at a rate to help you nod off but won't give you a nudge if you start to snore... yet



The biggest small music system

LS50 Wireless – Immerse yourself in power and finesse

Prepare to be swept away. Never before have bookshelf speakers produced such scale and detail. The KEF LS50 Wireless is a complete system that delivers audiophile-grade sound in real stereo. Five minutes from unboxing, just add your music and enjoy. No wonder respected reviewers call it the future of Hi-Fi. Listen for yourself.

24bit/192kHz    OPT APP CONTROL   TIDAL  Roon

KEF.COM



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OBSESSED WITH HIGH RESOLUTION

CANS FOR CONNOISSEURS

A good pair of headphones forms the heart of any decent hi-fi system. We test some of the best money can buy...

Choosing a pair of headphones should never be an afterthought when you're building a hi-fi system. A decent pair of cans isn't a mere accessory, or a necessary tool to ensure you don't annoy the neighbours or wake the kids up – the right pair can be your passport to a world of musical enjoyment you scarcely imagined existed, revealing hidden depths and unexpected, thrilling highs in even the most familiar of recordings.

It has to be said that this was one of the toughest group tests we've undertaken in a while. As you'd hope, given that these are four pairs of headphones from four highly respected manufacturers, all priced around the £500 mark, there isn't a sub-standard pair in sight. No try-hard contenders, no victories of style over substance, no disappointing 'will this do?' offerings from companies trading on former glories. If we met you in the pub and you told us you'd bought any one of the headphones on test here, we'd say "Ooh, nice" and shake our heads enviously, because we couldn't afford them.

That said, objectivity and close critical listening are the name(s) of the game. So over the course of many happy hours we put all four pairs through their paces, and here's what we found out...



BOWER & WILKINS P9 SIGNATURE

With their metal headband and earcups swathed in soft brown leather, the P9 headphones look like the kind you'd find in the listening room of a gentleman's club in St James's Square – a little old-fashioned, perhaps, but simply oozing quality. And they pack a musical punch.

As you'd expect from the closed-back design, the P9's are no slouches in the bass department. They deftly kept pace with the most frantic and intricate of jungle basslines and rendered the sonorous tones of Bach's *Toccata and Fugue in D Minor* impressively too, so whatever your choice of listening, there should be no grumbles here. Thankfully, mids and highs shine through brightly as well. The P9 headphones offer a slightly tighter, more compact sound than the airy Sennheisers and Quads, but again that's to be expected from the design. If pushed, you might say the midrange can get a little muddled at times (noticeable on Pink Floyd and Love albums), but honestly couldn't say if that was the fault of the cans or the recordings. Either way, we're firmly in nit-picking territory here.

The P9s do have a couple of major drawbacks. The first is that they are quite heavy and the second is a cable that's only 1m long. The in-line remote suggests the reason for this: they're primarily intended for use with mobile devices. There's nothing wrong with that, of course, and in a round-up of mobile headphones they'd no doubt wipe the floor with the competition. But no one wants to pay £700 to sit on top of their stereo. **7/10**



Type
Circum/supra-aural,
closed back, dynamic
Frequency response
2Hz-30kHz
Weight
413g
Price
£699.99
Details
bowers-wilkins.com

Type
Circumaural, closed back,
dynamic
Frequency response
5Hz-45kHz
Weight
294g
Price
£639.00
Details
audio-technica.com



AUDIO-TECHNICA ATH-A2000Z

First impressions upon taking the ATH-A2000Z headphones out of the box were good. With their shiny metal earcups and lightweight two-pronged metal headband with separately mounted cushions, they've got a satisfyingly 'space age' look about them, and they sport a nice long cable finished with a 3.5mm jack, as well as a screw-on 6mm adaptor included in the box. They're light and supremely comfortable to wear for long periods though they perhaps feel a little loose on the head, but otherwise there's nothing to grumble about in the looks and build department.

The Audio-Technicas impressed when it comes to sonic performance, too. The sound they deliver is incredibly detailed – they revealed a closed hi-hat tsk'ing away in Pink Floyd's *Brain Damage* that I've never noticed in 30 years of owning the album, while Nile Rodgers's screeching guitar on Chic's *Happy Man* shone through in exemplary fashion. If there's a criticism, it's that they're perhaps a little lacking in 'oomph' – Bernie Edwards' bass on the rest of Chic's album was forced to take a back seat it doesn't really deserve, while Love lacked a little of their usual exuberance. When it came to Illinois Jacquet and Flip Phillips's *Mayhem In Manhattan* live concert recording, though, none of the other headphones could quite give you that "being there at Carnegie Hall" feeling as well as the Audio-Technicas did.

All told, while they're perhaps best suited to lighter styles of music, this is a fine pair of headphones that definitely warrants a place on your listening list. **8/10**

SENNHEISER HD 660 S

The Sennheisers are the most affordable headphones in our round-up and that's reflected somewhat in their build: they're lighter than the other pairs on test and have a metal-and-plastic headband with foam rubber cushioning. They still look a very classy proposition, though, coming in a hardboard presentation case and, in true Sennheiser fashion, not only is the long, double-stranded cable user-replaceable, a spare is included in the box – as is a step-down 6mm-3.5mm adaptor. The headphones feel snug and comfortable on the head, too.

When it comes to their musical qualities, the open-backed design delivers a sound that's spacious and airy. This was particularly true with Forcione & Sciubba smooth jazz recordings, where the Sennheisers revealed each guitar note and breath with a crispness and clarity their closed-back rivals couldn't compete with. But there can be a downside to such high-end transparency, with the duelling saxes of *Mayhem In Manhattan* sounding a little shrill and screechy at times. Lower down the spectrum, Love's brass passages sounded a little muddy in places, while the intricate drum & bass twists of *JumpUpThrowDown* sometimes left the Sennheisers struggling to keep up.

Again, though, these are the kind of niggles that 99 per cent of listeners won't even notice and as long as your musical tastes don't skew too much in favour of bass-heavy styles, the Sennheisers offer solid build and quality sound at a far lower price than their rivals here, so they certainly shouldn't be dismissed. **8/10**



Type
Circumaural, open back, dynamic

Frequency response
10Hz-41kHz

Weight
260g

Price
429.99

Details
en-uk.sennheiser.com



Type
Circumaural, open back, planar magnetic

Frequency response
10Hz-40kHz

Weight
420g

Price
£599.00

Details
quad-hifi.co.uk

QUAD ERA-1

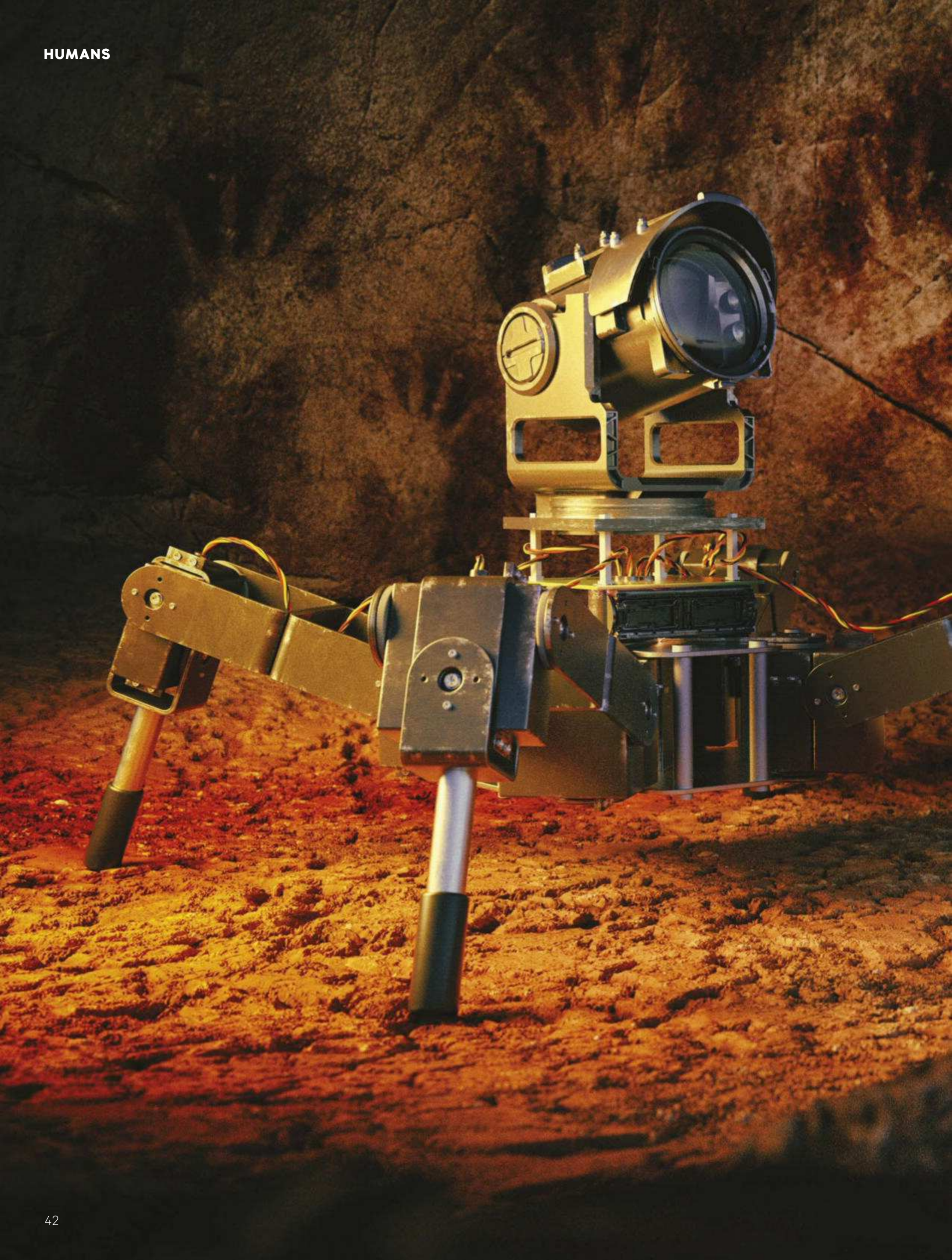
Uniquely, Quad's first-ever headphones deliver their sound using not a moving coil as in 'dynamic' headphones, but a ultra-thin, electrically active diaphragm, of the type also found in the British hi-fi stalwart's acclaimed electrostatic loudspeakers. That alone marks them out as special, but the hard clamshell carrying case, leather-encased metal headband, metal-grille earcups and sheepskin ear cushions also scream quality the minute you look at them.

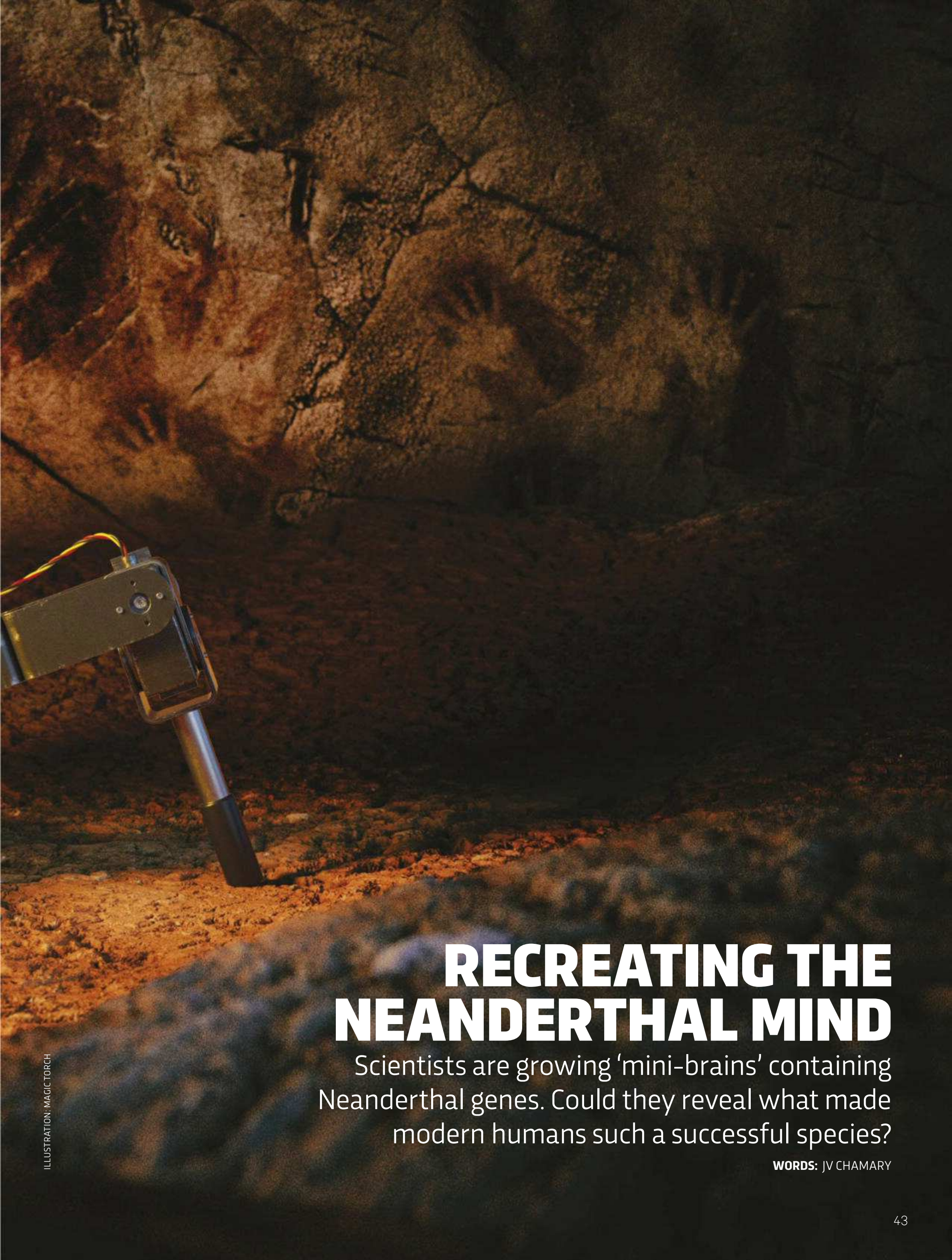
Quad claims its technology gives the ERA-1 headphones a more "natural and accurate" sound. It's certainly a warmer, smoother sound than their rivals here: you'll never experience ear-strain, although they are quite heavy. There's no faulting their definition right across the sound spectrum: high notes are bright without ever being shrill or piercing, mids are lovely and crisp, but perhaps the biggest surprise was in the bass department. These are open-backed cans, and by Quad's own admission, really optimised for vocal and acoustic recordings – yet for sheer bottom-end welly, we simply couldn't fault them. Bass tones did perhaps lack a little 'bite' at times, both on the drum & bass and the Chic albums, but then we were testing a factory-fresh pair and Quad recommends running the ERA-1 headphones in for a little while, so that would almost certainly improve over time. All told, this is one very classy set of cans indeed. **9/10**

VERDICT

The Bower & Wilkins P9 cans look and sound great, but they're aimed more at mobile use rather than home listening and are rather pricey. The Sennheisers, on the other hand, offer great value for money but they're just a little more 'ordinary' in terms of design and build. Both the Audio-Technica and Quad cans offer

great definition, but sound quite different: the Audio-Technicas are light and delicate, while the Quads sound warm and rich. The Audio-Technicas fared slightly better with bass-heavy styles, but we're sure the Quads would catch up in time and that, coupled with their sturdier build, makes them our winners, by a hair. **P**





RECREATING THE NEANDERTHAL MIND

Scientists are growing 'mini-brains' containing Neanderthal genes. Could they reveal what made modern humans such a successful species?

WORDS: JV CHAMARY

RIGHT: Neanderthals looked after their sick and their dead, as this reconstruction shows. They lived in small family groups and are thought to have had language

BELOW RIGHT: The demands of managing life in a wide social group is one explanation for the development of intelligence. Chimps can handle a bigger group than Neanderthals, while humans can handle bigger groups than chimps



Humans are the only living species of hominin, a tribe of great apes that also includes our shorter, stockier, stronger – and extinct – cousins, the Neanderthals. These prehistoric relatives originated in Europe, colonised Asia and were successful for almost 250,000 years. But within 10,000 years of ‘anatomically modern humans’ appearing in Eurasia, following our last migration out of Africa over 50,000 years ago, Neanderthals had disappeared.

While the cause of extinction remains controversial, many academics believe our ancestors outcompeted Neanderthals by being smarter. Archaeological evidence tells us that we had burial rituals, cave art and tools that surpassed anything created by the Neanderthals – all thanks to an ability to innovate. “We could solve novel problems better,” says Prof Fred Coolidge, a psychologist at the University of Colorado, Colorado Springs, and co-author of *How To Think Like A Neandertal*.

Unfortunately, we can’t go back in time to meet the Neanderthals and find out what made them tick. But new lab techniques are allowing us to do the previously unimaginable: recreate the Neanderthal mind in the lab. And it could give us the best chance yet of finding out why *Homo sapiens* survived while *Homo neanderthalensis* died out.

“Many academics believe our ancestors outcompeted Neanderthals by being smarter”



THE SOCIAL APE

The leading theory for why natural selection has favoured intelligence is the ‘social brain’ hypothesis: being intelligent is an adaptation for dealing with the complex interactions associated with living in groups. Humans manage 150-200 people, for example, whereas average group size in chimpanzees is 50. That figure can double, but tensions soon cause the chimpanzee troop to split. “Neanderthals couldn’t handle groups of more than 20-30,” says Coolidge. More relationships require more brain power and, in mammals, the size of a social group is correlated with the size of the cerebral cortex – the folded, outer layers of the brain, which are involved in higher thought processes such as language and decision making.

Larger groups enabled ideas to spread. “We are able to collaborate, to cooperate, and to share technology in a way no other species has done,” says Dr Alysson Muotri at the University of California, San Diego. “Part of that is due to the ability to communicate and interact among ourselves – and most of that seems to have evolved from the front of the cortex.”

To find out more about the brains of modern humans and Neanderthals, Muotri is growing organ-like





● structures made from cells from the frontal cortex. Could these organoids, or ‘mini-brains’, help explain what makes humans unique?

NEW GENETICS, OLD DNA

Growing organoids based on an extinct species is possible due to breakthroughs in several techniques: generating stem cells, extracting DNA from fossilised bones, and gene editing. Muotri is making organoids through a process that he calls ‘Neanderthalisation’. Here, he edits genes in human cells, replacing one letter of DNA with another – the genetic variant carried by Neanderthals – then prompts those cells to develop into pea-sized balls of cortex tissue. The Neanderthal variant is identified by comparing human DNA to the Neanderthal genome, which was first sequenced in 2010 by a team led by Prof Svante Pääbo of the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany. Incidentally, Pääbo’s lab is also creating Neanderthalised organoids.

One of the first human genes Muotri edited is NOVA1, a ‘master regulator’ which encodes a protein that controls when other genes are switched on or off. NOVA1 is known to be involved in early brain development because its mutations are linked to autism and schizophrenia. As organoids with the Neanderthal variant of NOVA1 mature, they develop defects in the synaptic connections between cells,

“Maybe in the future we will learn how to make all the brain regions and put them together”

ABOVE: DNA can persist inside bones for thousands of years. By drilling into the bone, you can extract the DNA. This is how Neanderthal DNA was first obtained

RIGHT: Mini-brains grown from human cells (left) and with a Neanderthal variant (right). The ones with the Neanderthal variant produce extra ‘popcorn-like’ folding

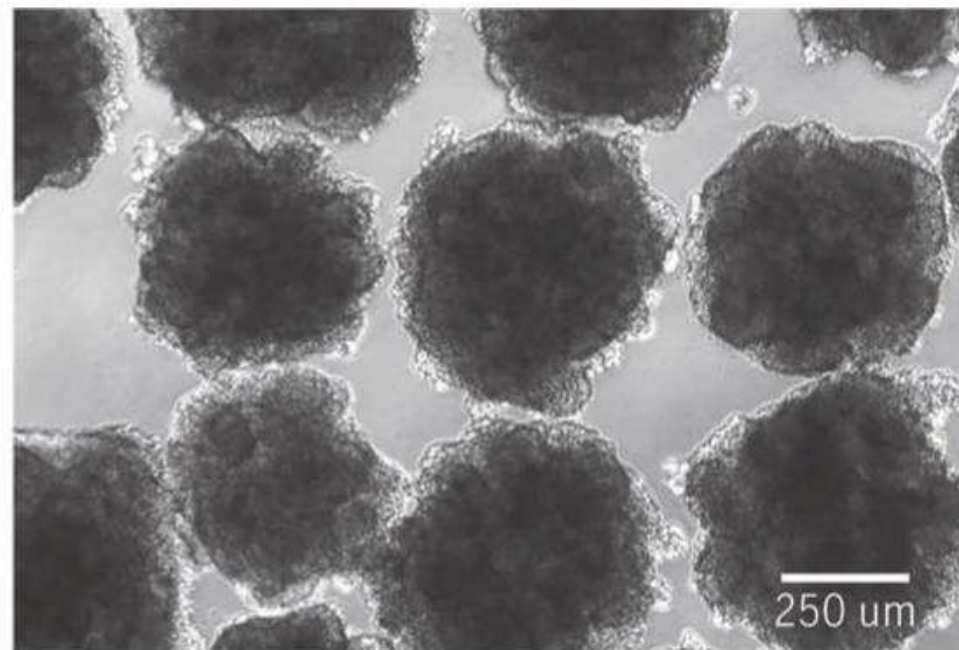
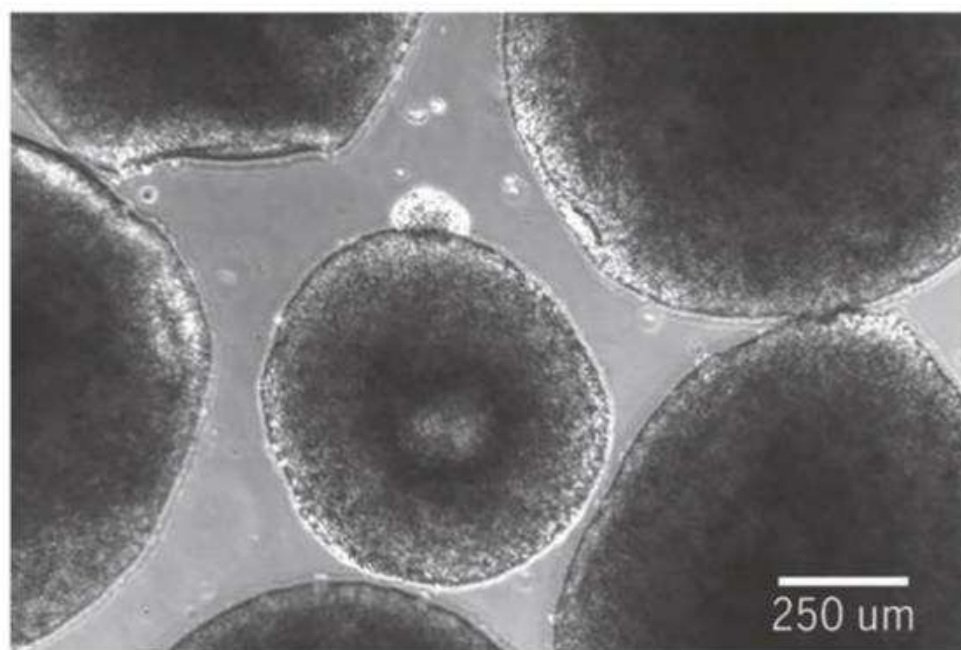
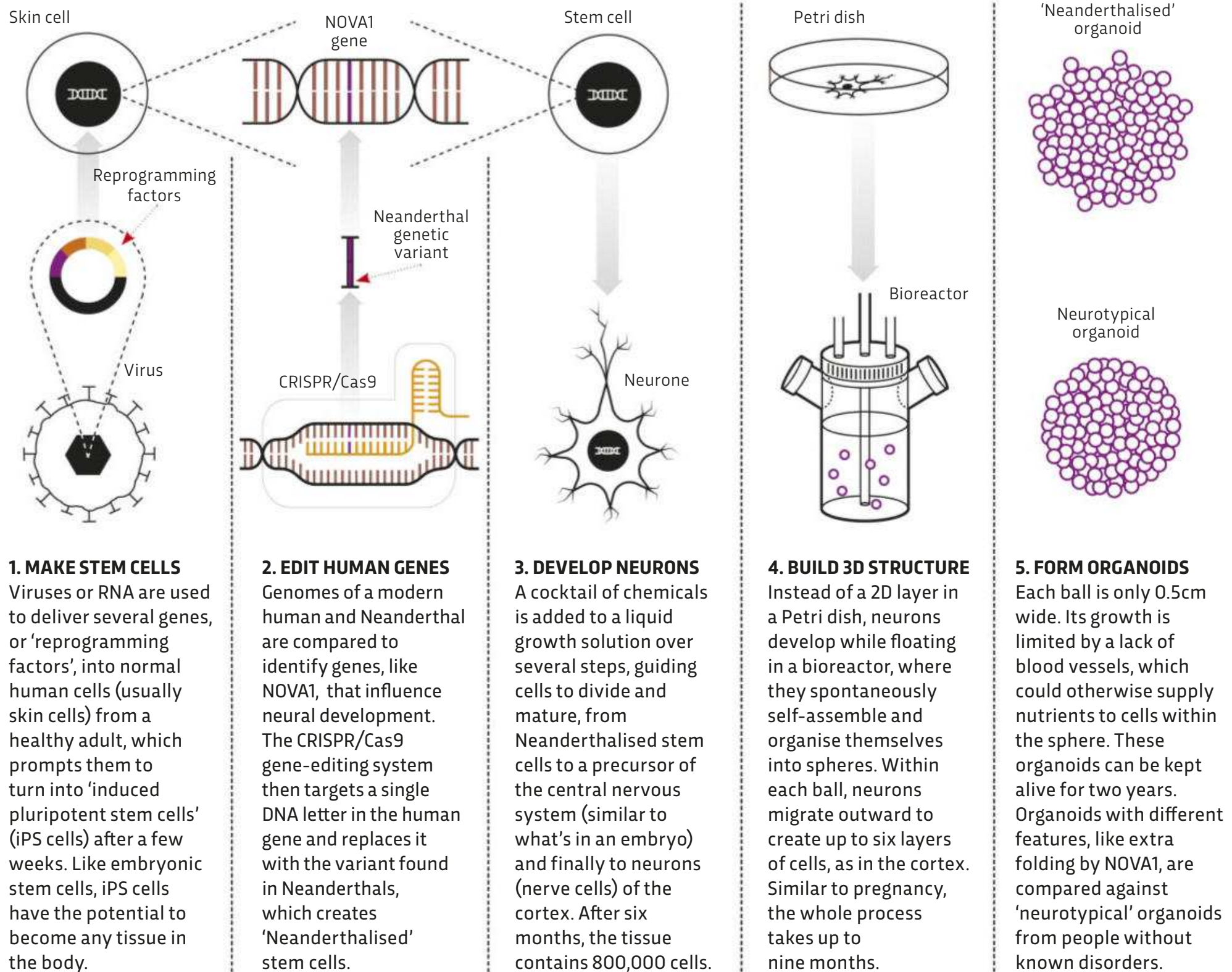
scrambling their neural networks. Neanderthalised cells within the ball also migrate in a manner that ends up producing unexpected extra folding, says Muotri. “They look like popcorn.”

But some scientists are sceptical that organoids will reveal much about our extinct cousins. “Human-type behaviour, and I include Neanderthals, is affected by much more than just the cortex,” says Coolidge, who points out that many daily activities, like walking and talking, are associated with ‘procedural memory’. This involves unconscious processes occurring in regions below the cortex, like the cerebellum, which is responsible for coordinating movement and is also linked to autism.

Acknowledging the limitations of studying the cortex alone, Muotri is hoping to grow a true mini-brain, ●

GROWING MINI-BRAINS

How Neanderthalised organoids are made from human stem cells





or ‘cerebral organoid’. “Maybe in the future we will learn how to make all the brain regions and put them together,” he says. Editing a single gene – NOVA1 – technically produces ‘partially Neanderthalised’ cells, so he’s now working to make a ‘fully Neanderthalised’ organoid, which requires replacing DNA letters in thousands of genes. “We are replacing chunks of the entire chromosome in these cells.”

The best model to study the human brain is in a living person, but society considers such experiments unethical, so scientists use surrogates – anything from a few cells in a Petri dish to grafting tissue onto a mouse brain. So where do mini-brains lie on the ethical scale? According to Prof Hank Greely, a bioethicist at Stanford Law School, they’re currently too small and simple to cause concern. “If organoids become larger and more complicated, then I think you’re a lot closer to having to worry about what’s in the dish.”

Regardless of which surrogate is used as the model for a living brain – human or Neanderthal – Greely says the key ethical question is the same: would it be entitled to special treatment? The answer isn’t based on whether it deserves ‘human’ rights, but on considerations that already apply to laboratory animals, like the capacity to feel pain (as detected through characteristic patterns of neural activity). Such barriers would probably prevent scientists from creating mini-brains capable of consciousness or becoming sentient.

But even if technical hurdles can be overcome and the research is passed by an ethical review panel, growing an entire Neanderthal brain may not offer enough insight into the lives of our extinct relatives, as it would be difficult to understand the behavioural

“The small echoes of Neanderthal DNA that we all harbour are active in modern humans”

impacts of any Neanderthal-human DNA differences in a brain that’s isolated from its environment. So if the aim is to understand the Neanderthal mind, why not grow a whole body too, by cloning?

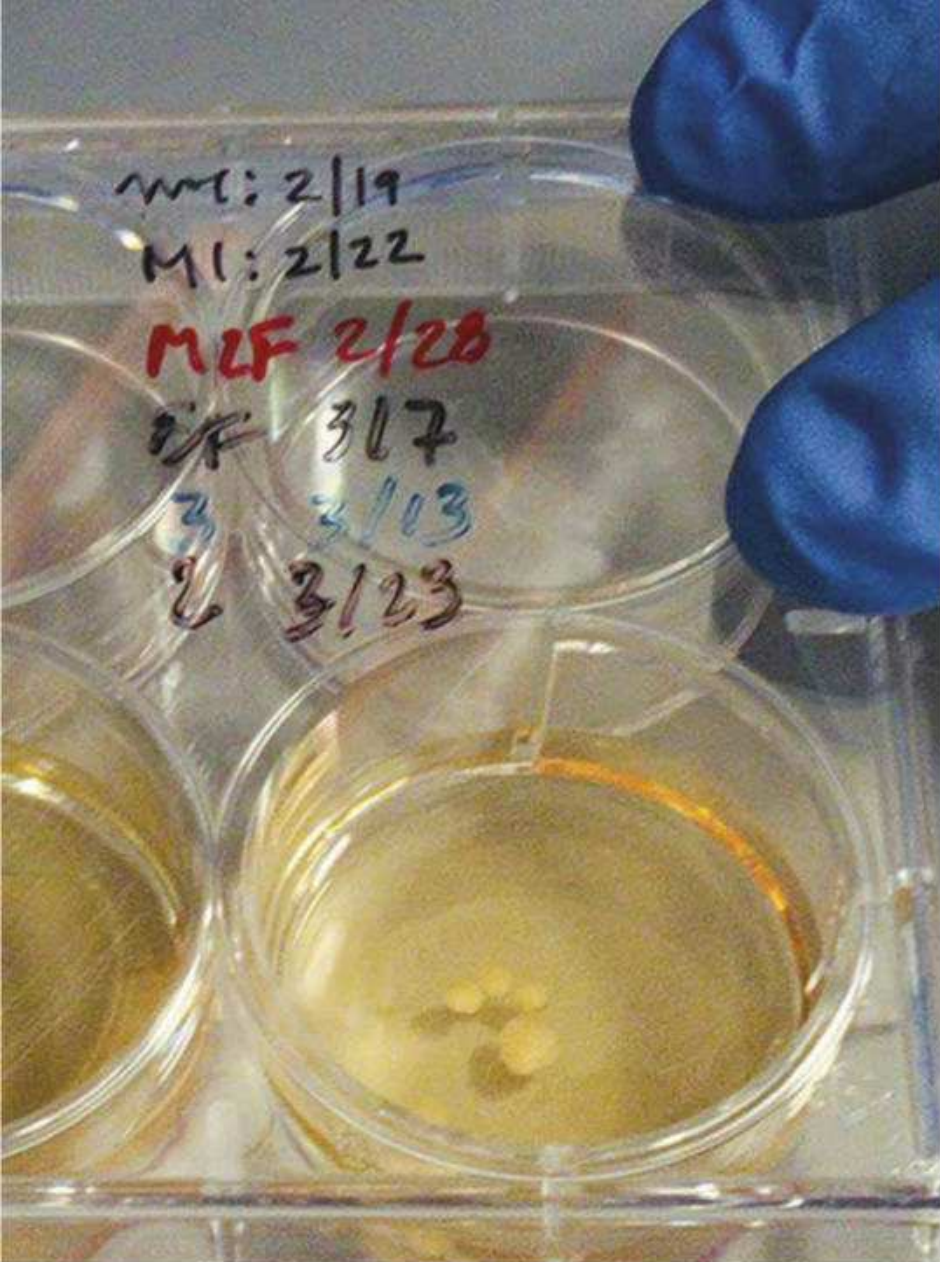
Cloning a Neanderthal has been suggested by renowned geneticist Prof George Church. It would involve extensive gene editing to generate a fully Neanderthalised embryo, implanted into a human mother. Bringing a Neanderthal baby kicking and screaming into the 21st Century means de-extinction of the species, and Greely says the ethical implications run deeper, as he suspects people wouldn’t be civilised enough to treat clones with respect, partly due to racism illustrated by the outdated ‘stupid caveman’ stereotype. “Even if we didn’t have that image, just knowing that they were not fully human would lead to discrimination,” he says.

MENTAL TRADE-OFFS

Views on our extinct relatives have shifted recently. While this shift can be explained by archaeological finds that show a more sophisticated Neanderthal culture than once assumed, the cynical explanation

ABOVE LEFT:
Neuroscientist
Alysson Muotri is
putting Neanderthal
gene variants into
human cells

ABOVE: Tiny
Neanderthalised
mini-brains, grown in
Alysson Muotri’s lab



is that the shift has only happened since present-day Europeans discovered that interbreeding occurred between the two species. Today, non-Africans carry about 2 per cent Neanderthal DNA.

The legacy of mating can still be heard in our anatomy. “Even the small echoes of Neanderthal DNA that we all harbour are very much active in modern humans,” says Dr Karen Berman, chief of the neuroimaging section at the US National Institute of Mental Health. In 2017, Berman and her colleague Dr Michael Gregory performed MRI scans on 221 healthy humans to construct 3D models of their heads. The work revealed that people with a greater number of ancient genetic variants – a higher ‘NeanderScore’ – have skull shapes that more closely match our extinct cousins, whose skulls were elongated at the back. (Although we associate size with smarts, the Neanderthal brain was actually 10 per cent larger.)

After sequencing DNA from the participants’ blood samples, Berman and Gregory found that a higher NeanderScore also meant the cortex had more grey matter (brain cells) and white matter (mostly branching fibres from cells). Folding of the cortex was greater too, mirroring Muotri’s popcorn-like organoids. The most affected areas were beneath the back of the skull: the occipital and parietal lobes of the cortex – regions that are involved in processing visual and spatial information.

The brain has limited resources, so allocating more to visual and spatial processing comes at the expense of other abilities, leading to a trade-off. Those genetic variants that influence how a brain’s resources are allocated seem to have given Neanderthals superior visual and spatial skills (probably for hunting), driven by ecological pressures to find calorific

BRAIN-POWERED SPIDER BOTS

Why are mini-brains being used to control robots?

Neuroscientist Alysson Muotri is putting organoids inside four-legged, spider-like robots. The main reason for such an unusual mind-machine interface is that it enables the ‘brains’ to explore the world around them – via an artificial body. “They’re similar to a newborn baby who’s trying to get used to touching things and experiencing different sensations,” Muotri explains.

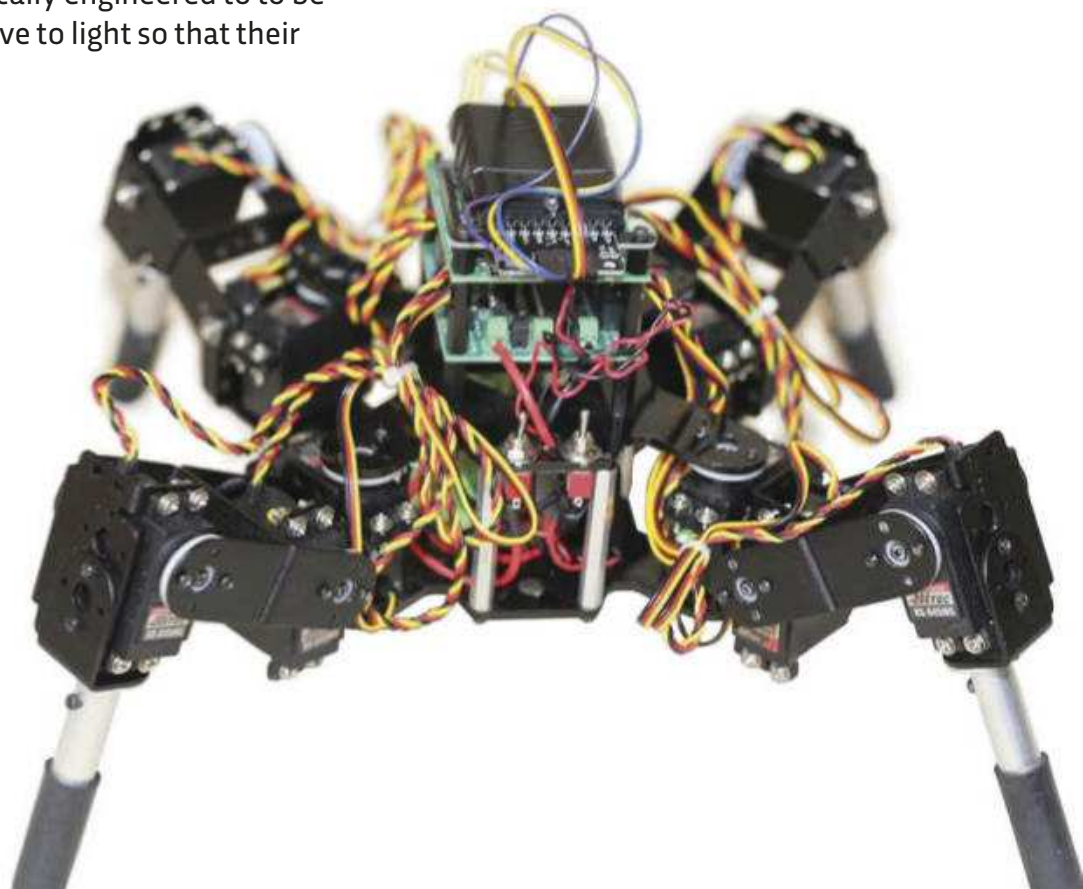
Electrical activity rises as an embryonic brain develops but reaches a plateau before birth, needing external input from the senses for its neural circuits to mature. In a spider bot, electrodes capture activity from the organoid’s cells and split the electrical output between the robot’s limbs, which must then synchronise. “In a very simplistic way, that’s exactly what the human brain does when a baby is trying to crawl or walk,” says Muotri. “So we’re teaching the organoid how to make this spider robot walk, by coordinating movements of the legs.”

It’s already learning. The ‘brain’ can currently tell its body to move forward; the next step is teaching it to go backward when it encounters an obstacle, which requires providing feedback for when a movement is wrong. That brain training is being achieved in two ways. The first method is a form of ‘mind control’ called optogenetics, in which cells are genetically engineered to be sensitive to light so that their

behaviour can be controlled. The second method involves supplying cells with a dose of the reward hormone, dopamine. Both methods cause the organoid’s neural networks to rearrange, allowing it to adapt.

Once organoids are able to learn, they can battle in robot wars – obviously not a fight, but a competition of speed. An organoid made from Neanderthalised cells with a NOVA1 gene variant has defects in synaptic connections between its cells, affecting its neural networks. Would that make it slower to adapt compared to a human organoid? While speculative, the results could offer clues on whether our human ancestors were faster at thinking, influencing their behaviour.

The spider bot, with its multiple legs, is allowing Muotri’s lab to observe how a single organoid handles coordination. One follow-up experiment would be to see how several organoids deal with cooperation. Would they interact to accomplish a common goal? The design for cooperating robots is still in the planning stages – it might involve two or three human-like arms that must work together to lift an object, or robotic versions of social insects like ants and bees. “This might sound like science fiction,” says Muotri, “but it is actually happening, and they have a clear purpose.”



“By understanding how the social brain evolved, we might be able to create better therapeutics”

● food to fuel an energy-hungry body in a cold climate. With modern humans, on the other hand, the trade-off meant that we had more processing power for social skills, contributing to our evolutionary success.

Ancient variants continue to affect humans today, as revealed by certain mental illness and neurological disorders. For example, ‘neurotypical’ people have one copy of a set of 25 genes located on chromosome 7, whereas a person with the condition ‘Dup 7’ has a duplication that creates two copies of each gene. This provides better visual and spatial skills but makes them less sociable – as in autism. At the other end of the spectrum, ‘Williams syndrome’ results from a deletion of those same 25 genes, leading to poor visual and spatial skills but hypersociability, which produces someone with a ‘gregarious brain’ who has a compulsion to strike up conversations with strangers.

So studying the impact of genetic mutations by comparing organoids, including those with ancient variants found in Neanderthals, can provide insights into conditions that affect modern humans. “This could provide information not only about what makes us who and what we are, but also possibly pave the way for treatment and diagnostic approaches,” explains Berman.

That’s actually the main reason why Muotri is growing mini-brains. His lab contains thousands of mutant organoids for various diseases. He’s already found that, like Neanderthalised structures, ‘autistic’ organoids have defects in their neural networks. “One misconception many people have is that by studying the evolution of the brain, there is no benefit to human health,” says Muotri, whose son suffers from autism. “By understanding how the social brain evolved, we might be able to create better therapeutics.”

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JV Chamary is a science writer and editor, with a background in evolutionary biology and genetics.

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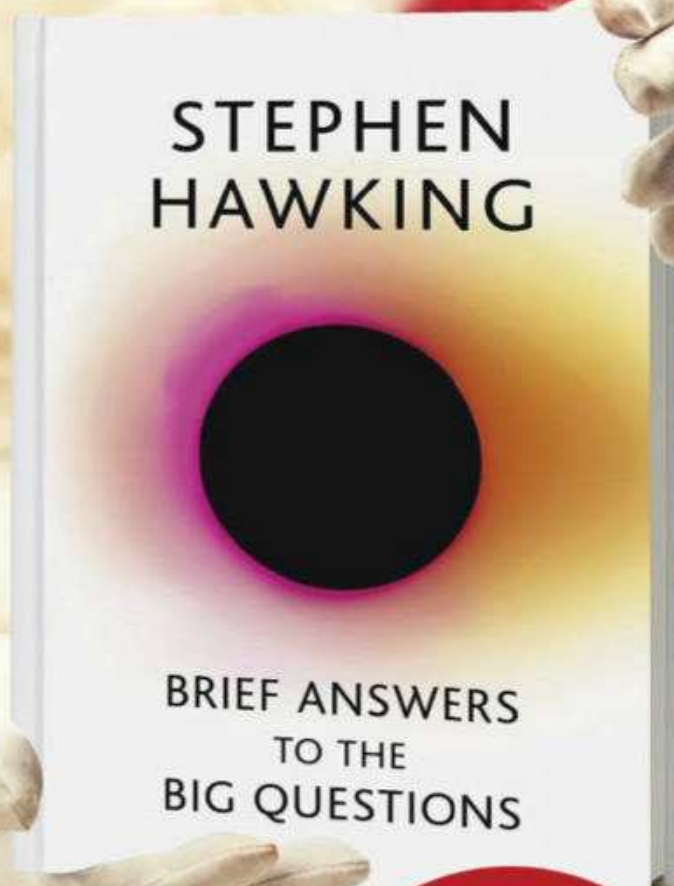
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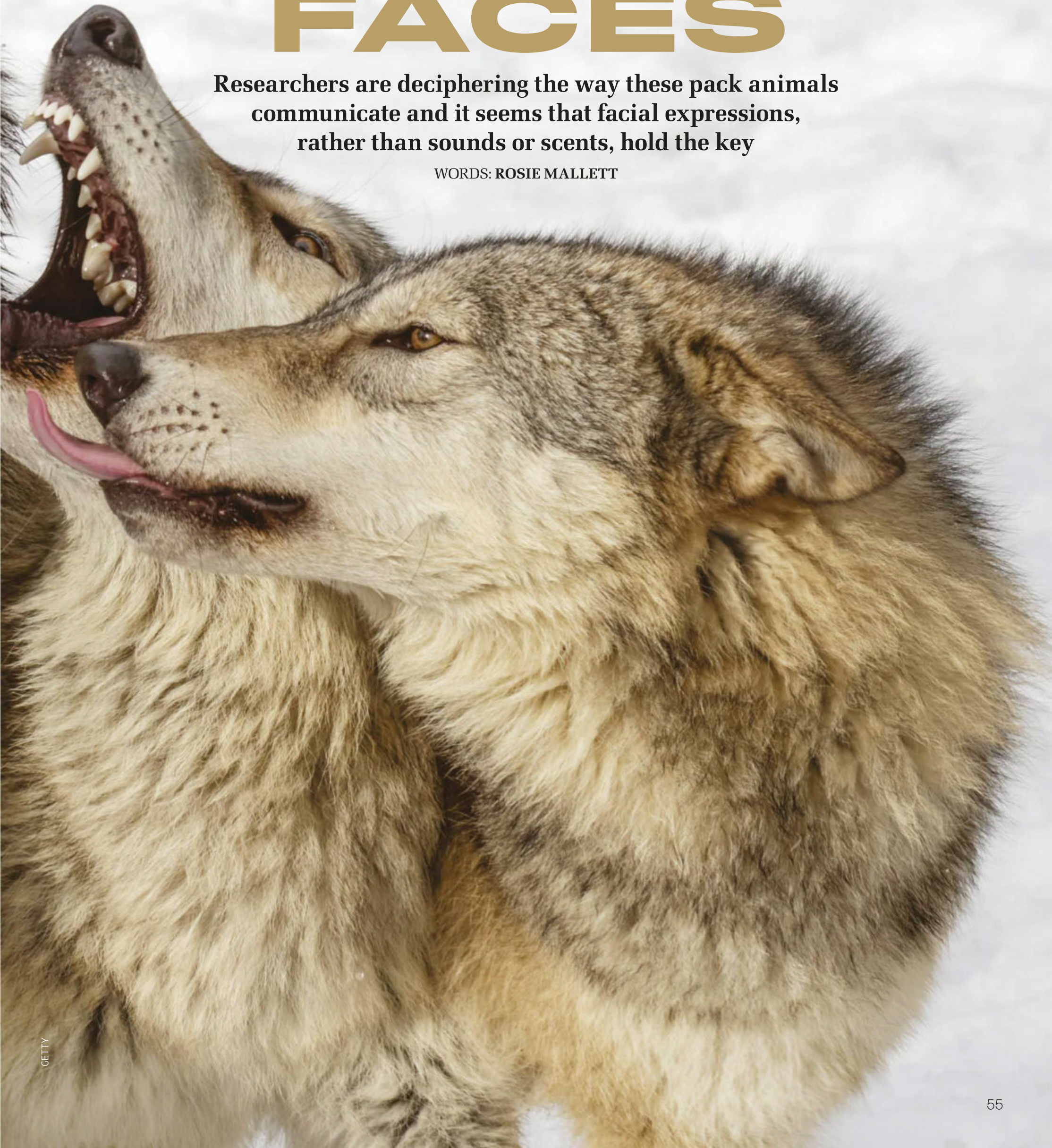
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WOLVES OF MANY FACES

Researchers are deciphering the way these pack animals communicate and it seems that facial expressions, rather than sounds or scents, hold the key

WORDS: ROSIE MALLET



Whether it's gobbling up Little Red Riding Hood's granny or blowing little pigs' houses down, wolves are traditionally cast as villains and portrayed as scheming, vicious and menacing. Now, thanks to the latest research, this looks set to change. Wolves are getting an image make-over. New studies are adding to a growing body of evidence that paints a very different picture of these animals and gives an intriguing insight into a sophisticated social structure centred around wolf family life. At the root of this is a complex level of communication built partly on facial expressions that reflect a wolf's feelings. In effect, wolves 'talk' by making faces at each other.

Researchers believe wolves may have used these communication skills to build bridges with hunter-gatherer people in an evolutionary journey that ultimately led to the domestic dogs we know and love today. In the first of its kind, research at Durham University is starting to translate this wolf talk and looks set to deliver important lessons about how we interact with our dogs at home and some disturbing news about our designer dog breeds.

"Most people think of wolves as nasty snarling creatures always ready to pounce on us. But this is nonsense," says Elana Hobkirk of Durham University's animal behaviour research group. "They are, in fact, sentient animals, capable of joy and friendliness as well as anger."

Hobkirk has looked at how wolves behave towards each other within the pack by identifying their

"The more subordinate members of the pack are more elaborate in their facial expressions"

facial expressions and determining whether they reflect the animals' underlying emotions. She has compared the results with those from dogs to see whether the domesticated cousins can produce the same range of signals.

This means getting up close and personal with wolves, which can be a problem. A wild wolf will flee as soon as it catches scent of a human, which means you'll be lucky to get within two miles of it, says Hobkirk. So, to get a good look at her subjects she has focused on captive wolves living in four packs at the UK Wolf Conservation Trust near Reading.

TAKEN AT FACE VALUE

"Although facial expressions have long been observed in wolves and dogs, this is the first time they've been quantified and correlated with their corresponding affective states [forms of motivation such as emotions, moods, attitudes, desires, preferences, intentions and dislikes]. Until now researchers haven't had the means to do it," Hobkirk says.

The technique involves filming the facial expressions of the wolves while they interact. The footage is then played back in slow motion so that their facial movements can be entered into a computer programme.

Each individual facial movement is allocated a specific code from the Dog Facial Action Coding System (DogFACS), a tool developed for use in dogs by Portsmouth University. It recognises each movement based on the underlying facial musculature that moves specific landmarks on the wolf's/dog's face such as eyes, ears, browridge, muzzle, nose and mouth.

The results are then correlated with the social context of the interaction to identify the emotions or affective states being expressed by the animal, using body language and outcomes of interactions as guides. "For example, if one wolf snaps at another, and the other wolf suddenly backs away, puts its ears back flat, lowers its head and shows the whites of its eyes, then that reaction is labelled as 'fear'," explains Hobkirk. So far the research has revealed that wolves can express at least nine emotions through their faces: anger, anxiety, curiosity, fear,

LEFT: Big, bad wolves are renowned in folklore for causing trouble for characters like Little Red Riding Hood, Peter and the three little pigs





ABOVE: Wolves' faces are typically longer than those of domesticated dogs, which makes it easier to discern their facial expressions

friendliness, happiness, interest, joy and surprise (See 'The Nine Faces of the Wolf', p58).

Along with other ways of messaging, such as body posture and vocalisations, the wolves use these facial expressions to build bonds between individuals and maintain their hierarchy within the pack. Apart from a few minor variations – one wolf might wrinkle its nose more than another, for example – these expressions are consistent across all the packs Hobkirk has studied. And it seems some wolves are more chatty than others.

"The more subordinate members of the pack are more elaborate in their facial expressions whereas the more dominant members don't have to make much effort to get the message across. They can just stand there and show who's boss," says Hobkirk.

One finding that has stood out from the research is a remarkable similarity with certain interactions used by primates in similar social settings. These include the 'jaw-drop', in which a wolf or primate relaxes their lower jaw and pulls back the corners of their lips so it looks like they're grinning without showing their teeth. It's an expression both species use to signal playtime and, in wolves, is different to the submissive grin, seen in expressions of 'friendliness', where the mouth is shut.

It's these similarities with primate expressions that have led the Durham group to the theory that wolves' communication skills may have played a key role in their domestication. Stone-age people and wolves could perhaps 'talk' to each other by using facial expressions.

Thousands of years ago, human and wolves may have formed alliances partly because they could interact through a range of signals, which we can still see today, albeit in a diminished form, in our domestic dogs. It seems obvious when you think about how much we rely on people's expressions to pick up on their meaning.

"It's natural for us to hone in on people's faces when we're talking. Research shows that people who have had a stroke and can't use their facial expressions as they did before, find it difficult to maintain relationships. As wolves also use facial expressions to communicate, then maybe millennia ago we were able to pick up on that and understand each other," says Hobkirk.

Domestication is thought to have started at least 15,000 years ago. It's possible human children may have taken a fancy to wolf pups and stolen them from dens, although some consider this unlikely given the time required to hand-rear wolf pups. Alternatively, wolves may have learnt that hanging around people was a handy way of scavenging food. In the process the humans gained extra protection from these animal allies who would alert them to dangerous intruders.

Whatever happened to bring the two species together, an alliance between human and wolf would have had benefits for both, according to Dr Sean Twiss, who heads the Durham University animal behaviour group.

"The accepted wisdom is that there was a mutual relationship between wolves and humans," he ➤

“Wolves share food and cooperate, whereas dogs don’t want to share, or reconcile after a conflict”

► says. “To enable that you need communication, so a variety of signals that effectively convey the wolf’s affective state to a human would be in its best interest if it is to get an advantage out of the association.” This could have served as a selection pressure as the two species co-evolved.

LOST IN TRANSLATION

So, after millennia of living together, you might expect us to be conversing happily with our canine friends. We know dogs are good at reading their owners’ faces and feelings. But it turns out that ‘man’s best friend’ is somewhat challenged when it comes to conveying emotions, at least via facial signalling. In her research, Hobkirk found only three consistent emotional states were detected in dogs by her model: anger, friendliness and joy. The problem is dogs don’t have the facial structure to pull faces to the same extent as wolves. Think of a pug – its flat face is a handicap when it comes to communicating.

“Dogs have more of a brachycephalic [shorter, flatter] face; long, flopped ears; long, pendulous lips; and a kind of weird hairdo that can hide their ears and eyes,” explains Hobkirk. “These are all features that can hinder communication. In breeding for looks, we’ve got rid of the more natural morphology that the dog needs.”

The problem may have started way back in the history of domestication. Previous research from Portsmouth University suggested that wolves with more puppy-like features may have been preferentially selected by people – and that this selection may continue today. But it seems we’ve gone too far and this has implications, not only for human/dog relationships but also for interactions between dogs. Some may struggle with the ‘language barrier’ and this may explain why certain breeds are more aggressive than others.

The Durham research also found domesticated dogs are twice as vocal as wolves – barking, yelping, whimpering, and growling. The extra noise could be to compensate for the lack of more subtle forms of facial communication – equivalent to the stereotypical Englishman abroad who shouts louder in his own language to try and be understood.

Wolves’ superior communication skills have also been observed at the Wolf Science Centre in Vienna, Austria. Here, assistant professor Friederike Range of the Konrad Lorenz Institute of Ethology and colleagues are studying the cognitive abilities of wolves and free-ranging wild dogs living in packs.

“Wolves are very social and dogs are not,” she says. “Wolves share food and cooperate, whereas the dogs don’t want to share, and they don’t reconcile after a conflict. The difference in communication between the wolves and dogs is striking.”

Wolves may also be more perceptive than pet dogs. In a recent study, the Viennese scientists found that dogs and wolves were both capable of finding a morsel of food if a researcher pointed to where it was hidden. But if the researcher just looked at the hiding place, only the wolves were able to follow their gaze to discover the food, explains Range. Dogs may be good at following commands, including pointing, but wolves pay more attention to faces and facial expressions.

THE NINE FACES OF THE WOLF

Video footage gives a better impression of the differences between expressions, such as anxiety and interest, but photos provide a good guide to what wolves can convey with their faces



ANGER
The animal opens its eyes wide, points its ears up and wrinkles its nose while snarling, growling and bearing its teeth. It may also snap its jaw.



ANXIETY
The wolf sucks in air through its lips, creating cheek depressions. It may also sniff and whimper.



CURIOSITY
With its ears pricked up, the wolf tilts its head and sniffs about.



FEAR
Fear is expressed by opening the eyes wide, raising the inner eyebrows, flattening ears back and sometimes also lowering the head.



Such abilities are doubtless what have earned the wolf its reputation for cunning. But it is the animals' impulse to live in packs and work together to support and protect each other that draws comparisons with human society. Wolves have a similar social structure to human hunter-gatherers, living in family groups and cooperating to hunt for food and provide for their young. A wolf pack is simply a family and can be as small as a pair of wolves but usually comprises the parents, the current year's offspring and those


ABOVE: A male Arctic wolf greets Elana Hobkirk of Durham University's animal behaviour research team

from the previous one to two years. A typical pack has about 10 members, although one pack in the USA's Yellowstone National Park, where wolves were reintroduced in 1995, reached 37 members of extended family.

Being in a pack requires a hierarchy in which each wolf knows its place. But aggression within a pack is usually only a small part of a wolf's life. Far more time is spent playing, says Rick McIntyre who during his 40 years in the US National Park Service, spent over a decade as the biological technician for the Yellowstone Wolf Project.

"Wolves are very affectionate to each other – licking their faces, play-wrestling, jumping up against each other, putting a paw over the shoulder of a companion," he says and goes on to point out that one dominant male would even pretend to lose at play-fights.

"The biggest and toughest male in the park would have a tussle with a smaller adult or a pup and would run off pretending to be afraid. It would be like a human father playfully wrestling with his son and letting the boy win," he says. "It's a good way to bond and build a strong relationship with each other."

Meanwhile, back in Durham the next stages of the research will look at the interaction between people and dogs. This could lead to a guidebook for how to talk to your dog with breed-specific cue cards included when you buy a dog. For example, if your pug is trying to convey anger or fear, it may use different signals to those of a Labrador or a German shepherd. Regardless, it seems that the best way to understand what your dog is trying to say is to learn to recognise the faces it's pulling. 

Rosie Mallett is a science journalist who has contributed to many consumer and medical titles including *Nature*



5

FRIENDLINESS

The wolf may blink frequently, raise its inner eyebrows, grin submissively and put its ears back flat against the head. It may also flick its tongue.



6

HAPPINESS

Happiness is being conveyed when the wolf blinks and raises its head. Sometimes its tongue can be seen near edge of its lower teeth but it isn't flicked.



7

INTEREST

With its ears pointing up and forwards, the wolf may bob its head while sniffing.



8

JOY

The wolf pulls the corners of its lips back and drops its jaw. It pushes its ears forward and sometimes may mouth another wolf without biting it.



9

SURPRISE

The eyes are wide and inner eyebrows are raised, while the ears are pointed up and forwards.



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WHAT MAKES US TICK?

Ella Al-Shamahi tells us why we need to listen to our body clocks

Everyone on Earth marches to the same beat: our bodies have an internal clock that keeps us on a 24-hour cycle. It's fundamentally important for our sleep cycle, but it's also crucial for our general health and well-being, and is linked to everything from our hunger and metabolism to our heart function, mental health and immune system. Studies have linked a disrupted body clock to a greater risk of diabetes, heart disease and cancer. With this in mind, James Lloyd caught up with Ella Al-Shamahi, an evolutionary biologist and presenter of a new *Horizon* episode on the body clock, to find out how we can hack our sense of time and why she locked a former Commando in a nuclear bunker for 10 days...

Why did you lock someone in a nuclear bunker?

Because we live in this modern, technological world, we don't really realise how powerful our body clock is, nor the factors that affect it. So the idea was: put a Commando [Aldo Kane is a former Royal Marines Commando] in an underground nuclear bunker, with no access to sunlight and no way of telling the time, and control his access to artificial light... and see what that tells us about our body clocks.

What exactly is the body clock?

It's our internal clock that keeps all our body functions in sync. It's regulated by a tiny region in the brain located in the hypothalamus, and it takes its cues from the day-night cycle of sunlight. The brain

uses nerves and hormones to transmit this 24-hour rhythm to our internal organs, which helps to tell our body when it needs to eat, sleep, wake and work.

As an evolutionary biologist, the really interesting thing for me is that the body clock is a highly 'conserved' mechanism, which means that it's stuck around for a long time in evolutionary terms – millions and millions of years. If something is highly conserved, that usually means it's pretty useful. Even fruit flies have a 24-hour body clock.

What did the bunker experiment involve?

There were three phases. In phase one, for the first few days, we didn't do anything other than just put Aldo down there and monitor him while he went about a normal daily routine – ►



☛ eating, sleeping, exercising, reading. We didn't give him any indication of what time it was. We were doing shifts monitoring him above ground, so we communicated with him via a tapping mechanism so that he wouldn't be able to work out what time it was by who answered the phone. He wasn't getting any natural sunlight, of course, but he could control switching the lights on and off within the bunker, so when he woke up he'd put all the lights on, and then when he went to sleep, he'd switch them off again.

The second phase of the experiment was what we called 'going dim'. We turned off all the lights, and we left only a dim lamp, so he was pretty much in darkness for a few days. We wanted to find out how the body clock coped when there was no light at all.

And then in the third phase we sent Aldo into jet lag mode. Usually, when you go into jet lag, perhaps when you're flying from New York to London, you have one disrupted sleep, but then you make up sleep over the next few days. But we woke Aldo up in the middle of his sleep at the same time for several days in a row, keeping him in constant jet lag. We weren't really giving him a break.

How did he cope with all this?

Not well! He was losing track of time – he thought it was a completely different time to what it actually was. And in the third stage, we were forcing him to wake up, so that kind of messed with him. He's someone who's tough, which is why we chose him for the experiment, but he was clearly losing it. It was partly the lack of contact with other people. But it was also clearly the fact that his body clock was out of sync. He was really miserable by the end of it.

What did you find out?

In the first phase, even though Aldo had no way of knowing the time, his body clock still broadly kept to a 24-hour cycle. He wasn't suddenly shifting to 36 hours, or 12 hours for that matter. So it's not your watch, or your phone, or the outside environment that's controlling that – your internal clock keeps its own time. But we could see that his sleep was shifting later and later.

When we turned off the lights in phase two, we saw that shift in Aldo's sleep pattern even more. Without any light, his body clock really struggled to keep time – it entered a stage called 'free running', which I think is a really great term.

Essentially it's where the body clock runs away with itself. We aren't sure why, but most people's clocks run slightly longer than 24 hours, and this is what we saw here. We need light to 'reset' and recalibrate our body clock.

I asked Aldo before he went in what time he normally woke up, and he said 6 o'clock every morning, with or without an alarm. I thought that was really interesting because here was somebody whose body wakes him up at 6 o'clock every day, but suddenly, when we took away his access to sunlight, he was shifting later and later. By the end of the experiment he was over three hours out of sync with the outside world. It's like those old winding clocks. You need to recalibrate them every day just to make sure that they're telling the right time.

During the film, I also meet a man called Mark Threadgold who lost his sight while serving in the British Army. Most blind people have some kind of light perception, but Mark's optic nerve was severed, so he doesn't see any light at all. He is constantly in that free running phase. Every day, he loses about an hour of sleep, so in the space of a month he does a full circle. He described how lethargic he was, and how it was really



Former Commando Aldo Kane volunteered to be shut in a nuclear bunker without access to natural light for Horizon's body clock experiment

ROBERT HOLLINGWORTH, GETTY

bad for his mood, so it really brought home the kind of impact this can have.

How can we apply these findings to our own lives?

What we put Aldo through was an extreme situation, but modern living is also quite extreme from an evolutionary perspective, in that a lot of us spend our days without much natural sunlight, which is something we're not designed for. So some of the advice is really practical. Maybe you can cycle to work instead of getting the train, or take a little walk outside during your lunch break.

Another interesting thing I found from talking to the researchers in the programme is that, just as our bodies have an overall 'master' clock, different organs also have their own clocks. So your ability to do certain things is governed by the time of day. We saw this with Aldo in his tests in the bunker.

I had always thought that you're supposed to work out first thing in the morning but, the truth is, I've never really been much good at doing that. It turns out that's not just me. In the morning, our bodies are still waking up, so it's best to wait until later in the day to work out. The morning is a good time to eat a big meal, though, because our metabolisms are more efficient then. It's better not to eat a big meal at the end of the day. So our digestive systems have a body clock, too.

Is there any way to completely re-tune our body clocks?

In the *Horizon* programme, I meet a couple who are struggling to synchronise their body clocks. Naomi is an early bird, while Greg is a night owl. They go to sleep together, but then Greg just faffs around in bed for hours until he finally gets to sleep. They really want to address that difference, because it disrupts Naomi's routine too, and they are getting married.

In a way, Greg is completely normal. Around 25 per cent of the population are night owls, while 25 per cent are early birds, and the rest are somewhere in between. We can't radically change where on the early bird/night owl spectrum we fall, but it *is* possible to shift our body clocks in a particular direction. Greg wanted to shift his body clock a bit earlier to match his partner's. So the sleep scientist in the programme gave him goggles that cut out blue light in the evenings [these fool the body clock



Ella learns that there are ways to reduce the effect late-night phone use has on our sleep patterns but the best approach is not to use them at all

“Just as our bodies have an overall ‘master clock’, different organs also have their own clocks. So your ability to do certain things is governed by the time of day”

into thinking it's darker than it is]. In the old days, if you wanted to work into the night, you had to light a candle. So you were already preparing yourself to go to sleep, whereas now you can have bright lights on up until the very second that you fall asleep.

Greg also started going outside more during the day to get that sunlight. If you're a night owl, you want to be getting outside in the morning sunlight, whereas early birds can shift their sleep a bit later by getting more sunlight in the afternoon.

With Greg, the changes really had a positive impact.


What other tips did you pick up?

To help your body clock keep a regular rhythm, aim to go to bed and wake up at around the same time every day. Try not to use your phone at night, but if you have to, use a night mode or blue light filter.

I meet another couple in the programme who both work night shifts – one of them really struggled to go to sleep, and the other one would sometimes sleep for 24 hours in one go. We sat them down with a researcher, who explained that they really need to be sticking to the same sleeping pattern every day, even on their days off. Keeping to the same timetable is much better for the body clock.

Something else that came up while making this film is the fact that most jobs are nine-to-five. But that 'one-size-fits-all' model is just not going to work for some people. If you're a night owl, it's no good expecting to be productive at 8 o'clock in the morning. It'd be great to move to a society where people can be flexible in their working times so that they can make their schedule work for them.

Have you changed any of your own habits?

My sleep is generally terrible and I don't respect my body clock at all, so I became slightly mortified at the impact I was having on my own health. I'm not a shift worker, but my sleep resembles one – I work really strange hours. So I'm now trying to stick to the same sleep routine every day. I'm trying so much harder since I did the show. 

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WHAT'S BRITISH



IN THE GUT?

**SCIENTISTS ARE SEARCHING FOR THE BACTERIAL PROFILE
OF BRITISH PEOPLE'S GUTS, AS THE SUBTLE DIFFERENCES
BETWEEN THE CONTENTS OF OURS AND THOSE OF
PEOPLE ON OTHER CONTINENTS COULD TELL US
MORE ABOUT OUR HEALTH THAN OUR GENES**

WORDS: AMY FLEMING

Species-wise, you probably identify as human. But based on the number of cells in and on your body, you are actually more microbe, because trillions of them call you home. Your human genes are outnumbered by microbial genes and, as the scientists exploring our microbial ecosystems (known as our microbiomes) are discovering, the armies of tiny freeloaders our bodies host are quietly controlling us. Together, they can govern mood, appetite and immune responses, as well as helping to digest and metabolise foods.

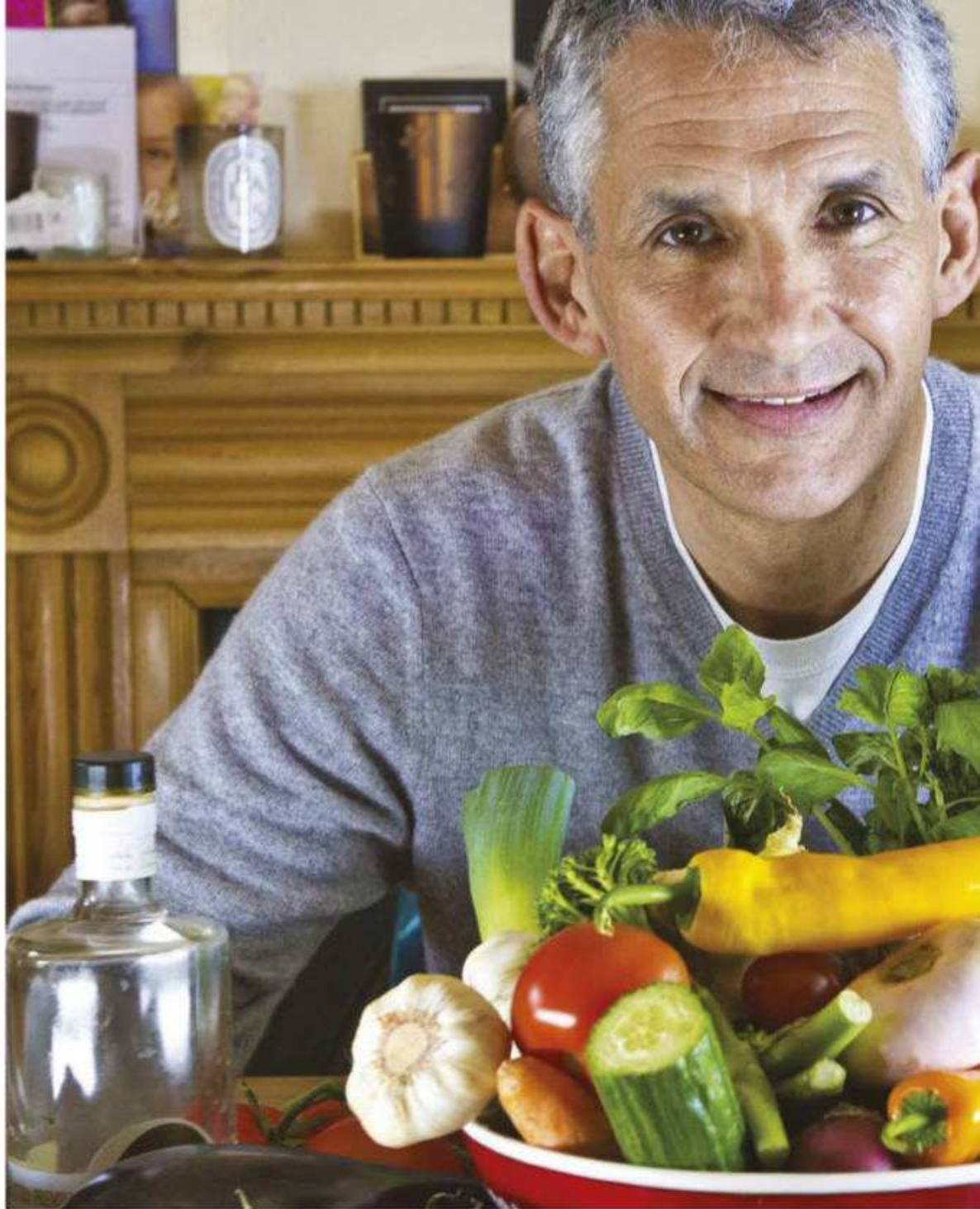
In some ways, our microbes are more influential in shaping who we are and how we feel than our genes, says Prof Tim Spector, who runs a microbiome research unit at King's College London called the British Gut Project. "I can tell more about someone's health by getting a detailed screen of their microbes than by screening their genes," he says, pointing out that we're 99.7 per cent genetically similar, whereas "we only share about 20 or 30 per cent of our microbes."

A CENSUS OF YOUR GUTS

Spector started The British Gut Project in 2014 to map as many people's microbiomes as possible, so as to reveal associations between our biomes and health. He had recently started studying stool samples from the vast King's College twins research registry he's led for 25 years, and was inspired by microbiologists in the US who had launched a crowd-funded study called American Gut. The shared aim of the British and American Gut projects is to build vast banks of gut data by inviting the public to participate. For a small fee, which is used to fund the work, participants get to discover which rare species they're harbouring, how their microbiome compares with others in their country and, says Spector, they're working on adding a "diversity score", because the more different types of microbes we host, the healthier we tend to be.

The samples collected by the British Gut Project are sent to the American Gut laboratory in San Diego for analysis. British Gut is, essentially, the European wing of American Gut, which is working with an expanding network of researchers around the world, seeking to do the same. All the resulting data are open source and will form part of the ambitious Earth Microbiome Project, a collaborative international push to characterise microbial life on Earth.

There are microorganisms such as bacteria and yeasts living all over our bodies, from toes to nose, which is why the British Gut Project will also accept swabs taken from skin, mouths and vaginas. But the control centre lies in the gut, which some researchers somewhat creepily refer to as the second brain. (Finally there's a scientific basis for the idea of 'gut instinct'.) By analysing the living contents of our guts via stool samples, researchers can identify geographical differences – such as American microbiomes tend



"THERE ARE MICROORGANISMS LIVING ALL OVER OUR BODIES... BUT THE CONTROL CENTRE LIES IN THE GUT, WHICH SOME RESEARCHERS CREEPILY REFER TO AS THE SECOND BRAIN"

to be less diverse than their British counterparts – and links between certain microbes and common diseases.

Currently, says Spector, microbiome knowledge is 10 years behind human genetic research. We've only scratched the surface in identifying all the microbes, learning what they do and how they work together. But we have identified a group of microbes that seem to be beneficial in most people. People with diabetes, rheumatoid arthritis, food allergies, irritable bowel syndrome (IBS), colitis and high blood pressure, says Spector, "tend to lack these beneficial microbes that in other people are protective."

There are strong links, also, between mental health and gut health. Prof Felice

ABOVE: Prof Tim Spector believes a diet consisting of a diverse range of plants and whole foods promotes a more diverse microbiome



Jacka, who runs the Food and Mood Lab at Deakin University in Australia, first established the field of nutritional psychiatry a decade ago and her research is increasingly turning to microbes. “All the factors that underpin depression from a biological point of view are under the regulation of the gut microbiome: inflammation, brain plasticity, immune activation in the brain, gene expression. It also affects the level of neurotransmitters in the brain and has a very important role in modulating the stress response system,” she says.

Even the effects of foods and drugs on our systems (from antidepressants to cancer chemotherapy) are related to the microbes we have. “If you’re on cancer chemotherapy,” says Spector, “and you have the right type of microbes, you’ll be three times as likely to survive. So everybody going onto cancer chemotherapy should be getting their microbiome tested.” If it’s found that you don’t have the necessary microbes, taking probiotic supplements containing helpful bacteria and making dietary changes, he says, may well improve your chance of living. “American cancer centres are ►

INTESTINAL INHABITANTS

WHAT’S IN YOUR MICROBIOME?

1 Bacteria

The gut microbiome is a complex, ever-changing ecosystem of microorganisms that collectively can weigh up to 2kg – heavier than an adult human brain. Your thronging gut world is dominated by about 100 trillion bacteria, some are nasty, but many are essential to keeping our minds and bodies functioning healthily.

2 Fungi

Less is understood about what scientists refer to as the ‘silent population’ of gut-residing fungi, such as *Candida albicans*. They only account for about one per cent of the microbiome, but they live in symbiosis with the bacteria and other microbes. Scientists are only just starting to study their role in the gut community in terms of disease susceptibility and immunity.

3 Yeasts

Yeasts are simply single-celled fungi.

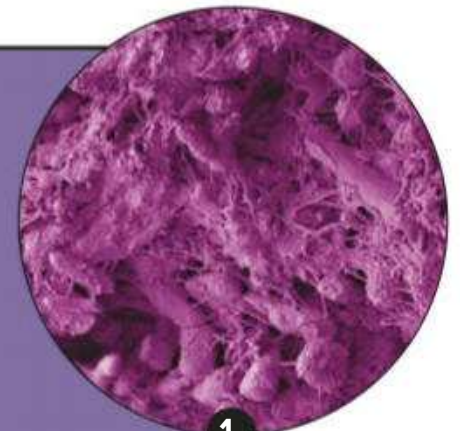
The aforementioned *Candida albicans* is a yeast, which is why too much of it can be referred to as both a yeast and a fungal infection.

4 Protozoa

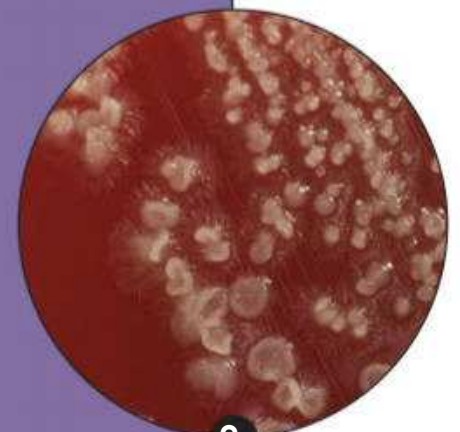
These single-celled organisms were once classified as animals; they can move independently, be predatory and feed on organic matter. Most of them are harmless, and some are even being investigated as potential do-gooders, but others can cause terrible diarrhoea and are a strong reason to wash your hands before eating.

5 Archaea

These tiny wonders are more usually found living in hot springs. But among the handful that inhabit the human gut are important members of the ‘A-team’ of microbes, which support the complex process of digestion for us by playing an essential role in breaking down complex sugars.



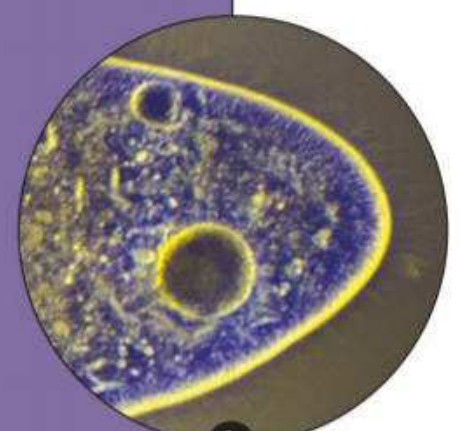
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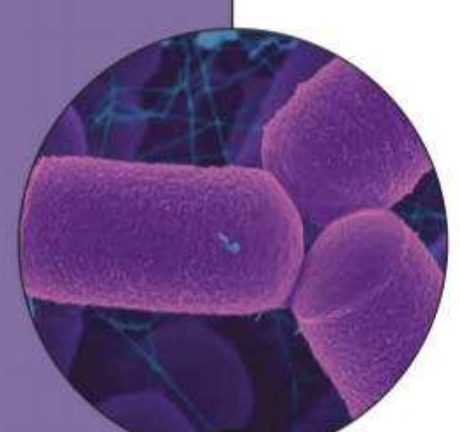
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**“THERE ARE WAYS THAT YOUR BODY
CAN WARN YOU THAT YOUR GUT FLORA
ISN'T FLOURISHING. HAVING IRRITABLE
BOWEL SYNDROME CAN BE A SIGN,
ALONG WITH BEING CONSTIPATED”**

➤ now routinely screening their patients and offering advice,” notes Spector, whereas the gut-chemo axis hasn't reached British doctors' agendas yet.

This is one among many examples where taking probiotic supplements has been shown to be effective. “It's looking like they do work for a wide variety of conditions,” says Spector. “If you've got a child with diarrhoea, giving them probiotics will significantly speed up recovery time.” Jane A Foster, associate professor in psychiatry and behavioural neurosciences at McMaster University in Canada, describes the probiotics industry as a “flourishing landscape” and foresees a time when probiotics will be in our orange juice and chocolate bars. But she warns probiotics aren't always the solution. “The microbiome is partly driven by our own genetics and partly by environmental factors such as stress, diet, age and gender. All these things affect the composition and they probably also affect the function of the bacteria that are there.”

In other words, it's not simply a cause and effect relationship between the amount of good and bad

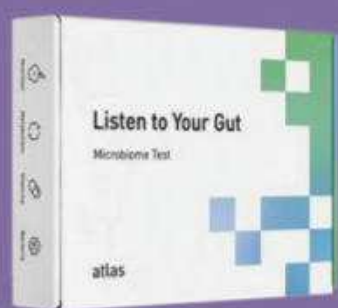
bacteria in your gut. “The only way bad bacteria's effects are understood is when we have enough of them to constitute an infection and we have terrible gastrointestinal symptoms such as vomiting and diarrhoea (due to *E. coli* or *C. difficile*, for example),” explains Spector. “In terms of our gut flora, it's not yet possible to prove a causal role for any bacteria, as it's not understood how they all interact in the body. Many of them can't survive outside the body so we can't study them in action. The way scientists find out about what bacteria we have is by finding their DNA.”

HAPPINESS IS A HEALTHY GUT

There are ways that your body can warn you that your gut flora isn't flourishing. Having IBS can be a sign, along with, says Spector, “being constipated, having a limited diet, feeling bloated; on average, if you're overweight, unwell and have lots of allergies, you're going to have poor gut health.” For many, he says, this is the norm and it's only when you change it and begin to feel better that you realise how bad it was. Your immune system improves and you have fewer colds and infections.

To improve gut health, Spector advises doubling your fibre intake – eating whole foods, such as grains and beans, and plenty of fruits and vegetables. Fermented foods such as yoghurt, sauerkraut and the national pickle of Korea, kimchi, are packed with friendly bacteria. And according to Spector, the number one

MAIL-ORDER GUT TESTING



For £139, Atlas Biomed will provide a breakdown of your gut flora's diversity, its ability to digest fibre, your susceptibility to diseases such as ulcerative colitis, Crohn's disease, obesity and type 2 diabetes, and the nationality your diet most resembles. You will also receive personalised dietary advice on how to strengthen your microbiome through diet. atlasbiomed.com



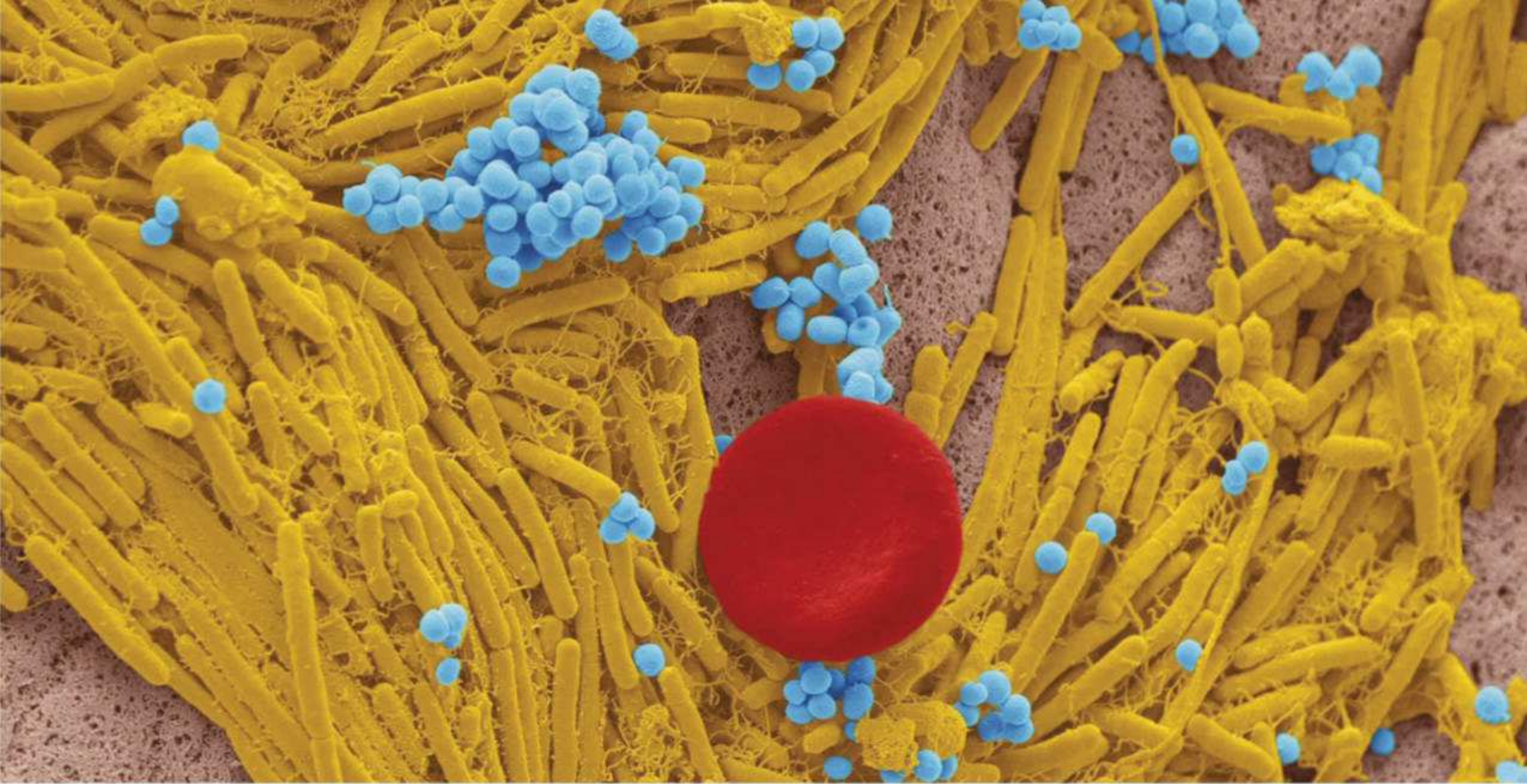
UBiome offers tests on bacteria from your gut, mouth, nose, genitals and skin – the basic UBiome Explorer kit costs \$89 (£68) plus postage to the US. The results will compare your gut health with vegetarians and meat eaters, assess the diversity of your microbes, and how well your flora will metabolise carbs, caffeine and other substances. ubiome.com



As well as offering a gut-health test for \$150 (£115), Thryve also sells packages that deliver a health report and food recommendations along with probiotic supplements (on a monthly subscription, if desired) and a step-by-step diet plan. Thryveinside.com



With Carbiotix, the emphasis is on boosting the friendly bacteria in your gut by feeding it the soluble fibre, through diet and Carbiotix's prebiotic supplements (essentially fertilisers for your gut flora). To avoid filling yourself with more fibre than your bacteria can eat, Carbiotix tests your gut flora monthly so you can monitor the situation and build your flora and fibre intake accordingly. It's among the cheapest tests going, at €19 (£17) a month or €49 (£44) with a personalised prebiotic supplement. Carbiotix.com



ABOVE: There are around 1,000 species of bacteria living on your skin – seen here are a few of the species (and a red blood cell) found in a swab from someone's fingertip

result so far from the British Gut Project (which has had nearly 6,000 participants) is that the people with the healthiest guts consume the most diverse number of plants. “Whether you’re vegetarian, a carnivore, on the paleo diet or whatever, if you get a range of plants on your plate – be they seeds, nuts, spices, herbs, fruits, vegetables, mushrooms, grains – it’s the variety that’s key.”

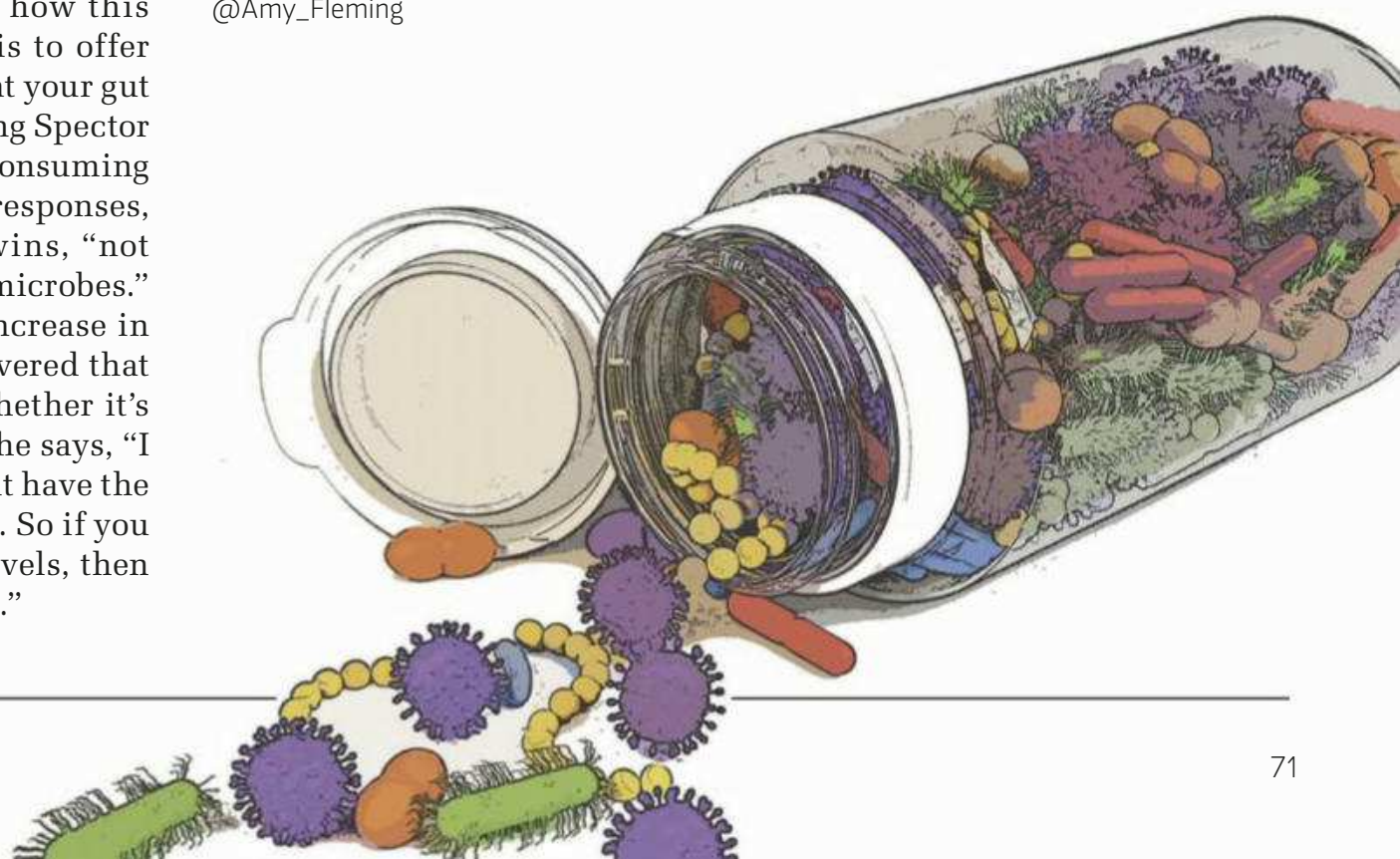
Peak gut health corresponds with eating 30 different plant foods each week, and American Gut reports that those in this group were also found to have the least antibiotic-resistant bacteria genes in their guts. The researchers wondered whether this could be because the participants were eating less meat and processed foods tainted with antibiotics. (Unsurprisingly, they found that taking a course of antibiotics within the past month resulted in a less diverse microbiome than in those who hadn’t taken these medicines in the previous year.)

Spector has since launched a second phase of gut research, called the Predict Study, which looks at personal responses to different foods and how this corresponds with the gut flora. The goal is to offer personalised nutritional advice by looking at your gut microbes. Participants in the study, including Spector himself, test their blood glucose levels after consuming everything from bananas to prosecco. The responses, he says, vary widely, even in identical twins, “not because of their genes but because of their microbes.” Frequent glucose spikes are related to an increase in weight and diabetes, and Spector has discovered that these occur in him when he eats bread, whether it’s white or wholemeal. “If I eat pasta or rice,” he says, “I don’t get a spike, whereas other people might have the opposite. It’s the microbes determining that. So if you can find foods that support your glucose levels, then you’re more likely to lose weight long term.”

This is one of the reasons why he believes microbe testing will end up becoming routine. Web-based microbiome testing services are already around £100 he points out, “and as more people use them it’s going to go down to £50. If the NHS did it, the price would be below £20 – the same price as a blood test and instantly more useful.”

Eventually, he says, “I could test your gut microbe and say, based on our database of 10,000 people, whether you should be a rice person rather than a potato person.” One British and American Gut finding already defends alcohol in the ongoing scientific debate over whether any booze can ever be healthy. Happily for moderate drinkers, those who consume alcohol once or more per week have more diverse microbiomes than abstainers. And as the numbers get bigger, more detailed and subtle geographical differences will become clear, along with gut signifiers of disease and the effects of specific diets. 🍷

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HOW TO STOP ELECTION HACKING

WORDS: KATE O'FLAHERTY ILLUSTRATION: JOHN HOLCROFT

Can technology safeguard the vote ahead of this month's US mid-term elections?

Back in March 2016, Hillary Clinton's campaign chairman John Podesta accidentally clicked on a 'phishing' link, allowing Russian-affiliated hackers to access his emails. It was the latest in a series of successful attempts to infiltrate the National Democratic Committee's systems and discredit Clinton's campaign. By the end of the same year, these breaches had become the centre of an international outrage and Republican candidate Donald Trump had been elected as president.

It took two years to prove the hacks on the National Democratic Committee were the result of foreign actors' attempts to influence the US election. But finally, in 2018, an indictment was issued against 12 members of GRU, the Russian intelligence agency, alleging they took part in a "sustained effort" to hack the Democratic Party's systems during the 2016 presidential campaign.

The US is determined to stop hacking affecting its mid-terms when they take place on 6 November. But this will be a challenge, partly because nearly every model of its electronic voting machines is vulnerable to hacking. The issue lies in the fact that many of the machines lack robust security because they were not built to be connected to the internet – and those that do include security measures possess glaring holes.

The ease with which electronic voting systems can be manipulated was proven at the Def Con cyber security conference in 2017, when democracy-tech researcher Carsten Schürmann used a vulnerability to gain remote access to a WinVote machine within two minutes. During

the same conference in August 2018, two 11-year-olds managed to hack into a replica of Florida's election results website in under 15 minutes, changing names and tallies.

All this has proven that moving voting online is risky. But it hasn't stopped countries offering people the chance to cast their votes electronically, rather than using traditional paper ballots. Estonia has offered online voting for more than a decade, with citizens proving their identity through state-of-the-art electronic ID cards. Yet even this method isn't infallible: in 2017, scientists found a security flaw in the cards that would allow a potential attacker to steal someone's identity.

Other attempts at online voting have been abandoned due to cyber-security fears. Norway tested online voting during parliamentary elections in 2011 and 2013, but this was discontinued after political disagreement and voter concerns.

In the UK, the election system is designed so it does not lend itself to electronic manipulation: voting and counting of ballots are "manual processes conducted under the watchful eye of observers", says Dr Ian Levy, technical director of the National Cyber Security Centre (NCSC).

FOREIGN ACTORS

In contrast, the US will look to electronic voting machines to allow citizens to vote in this November's mid-terms. But these machines are often based on outdated operating systems such as Microsoft's Windows XP, which are too old to receive security updates and, as a result, particularly vulnerable to hacking.

Weaknesses such as these are an easy target for the foreign and domestic actors interested in hacking elections. And although there is no solid evidence of successful attacks on online voting or counting systems yet, experts say it is only a matter of time.

"We can make a system that is end-to-end secure, but if it's then layered on top of something insecure, a hacker will look for the lowest hanging fruit and it won't make any difference," says Professor Robert Young, of Lancaster University.

Adding to this, hackers are taking steps to understand the weaknesses in electronic voting machines. "Lots of machines find their way onto the second-hand market," says Rodney Joffe, a former cyber-security adviser to the White House. "This gives a potential attacker the opportunity to experiment at will."

Other election hacks are designed to influence voters or to undermine public confidence in the polling process. Attackers will combine breaches of physical systems with tactics such as fake news and disinformation, which were used by would-be hackers during the recent French and German elections. ●



QUANTUM MECHANICS CAN BE USED TO PROVIDE IDENTITIES

● Hackers will try to create doubt, even if they don't modify anything. They could do this, for example, by manipulating the electoral roll.

The electronic poll books used in place of the paper rosters of registered voters are at risk of attack, says Joseph Lorenzo Hall, chief technologist at the Centre for Democracy and Technology in Washington. This could see hackers erase or change data, potentially stopping people from being able to vote.

More generally, he also expresses concern about cyber-attacks such as denial of service, where hackers flood election websites with traffic to make them unusable. "This affects people's faith in systems."

SECURING ELECTIONS

Several companies and organisations are already taking steps to secure elections. Matthew Prince is CEO of Cloudflare, which offers cloud services to government bodies at no cost to protect election infrastructure. The firm protects all parts of election security outside of voting booths, such as registration sites.

Another suggestion for securing elections gaining traction in the European parliament is blockchain – a list of records linked together using cryptography. The technology is widely known as the basis for cryptocurrencies such as Bitcoin, but it can be used in other ways too.

"People get excited about blockchain because it can create locked-down data that is difficult to change," says Catherine Hammon, digital revolution knowledge lawyer at Osborne Clarke. "You can set things up, in theory, so no one can see who you are and how you voted." This method is being tested to secure elections in several

countries. In March, when Sierra Leone's presidential elections took place, votes in the Western Districts were registered on a blockchain ledger by Swiss-based firm Agora. Voters still marked paper ballots, which were then manually re-coded and uploaded onto a blockchain network. Meanwhile, an interesting trial is currently taking place in West Virginia in the US. First conducted during the 2018 Primary election in Monongalia and Harrison Counties, the pilot allows

military personnel and their families stationed overseas to cast an official ballot using a smartphone app.

The app, developed by a start-up called Voatz, employs blockchain technology to ensure that once submitted, votes are verified and stored on multiple, geographically-diverse servers. The initial trial was a success and it's currently being rolled out to all of the state's 55 counties to be used in the mid-term elections.

It offers potential for the future, but observers point out there are still problems with blockchain-based election security. "It won't stop someone holding a gun to your head to force you to vote a certain way," Hammon says.

It is also difficult for the technology to verify potentially hundreds of millions of voters in the time required. Hammon cites the example of the UK Brexit referendum, in which over 30 million people voted. "If blockchain verifies in seven seconds, the vote could take up to 55 days depending on the structure used."

Other innovative security measures have also been suggested. Some think the answer to securing online voting lies in quantum systems, which could provide a way to produce truly random prime numbers – a key challenge in secure internet transactions.

Quantum key distribution – a method of secure communication using laser beams to transmit cryptographic keys – was used to send the results of Swiss elections securely from local centres to the State of Geneva's central data repository. Prof Young, who has been working on applying quantum mechanics to cyber-security, says quantum key distribution can help by detecting people interfering with communications.

PROVING IDENTITIES

More generally, quantum mechanics can be used to provide identities. Known as atomic fingerprinting, quantum mechanics can be used to magnify the effect of imperfections in devices. "This allows us to 'fingerprint' them for identification and authentication," says Prof Young.

Embedded within any electronic device such as a processor, these could be used in a simple way, to prove the authenticity of a voting machine when it

The WinVote electronic voting machines used in American elections have been shown to be vulnerable to hacking





communicates the votes cast back to the main server. “This could be used in tandem with quantum key distribution to also guarantee that the communications haven’t been altered or eavesdropped upon,” Prof Young adds.


At the same time, quantum mechanics can be used to generate numbers for creating cryptographic keys. Current systems tend to generate random numbers

poorly, making cryptographic keys predictable so it’s possible to hack communications. “Most communication protocols use random numbers to create cryptographic keys and we can apply quantum mechanics to generate these more effectively,” says Prof Young.

But he admits there are major challenges when using quantum systems to secure elections, including the feats of complex engineering needed to ensure systems behave as they are supposed to. In addition, the quantum systems are very expensive, costing up to tens of thousands of pounds, so it’s not feasible to simply place them inside voting machines.

In reality, securing elections, at least in the short term, could come down to just a few simple processes. David Forscey, policy analyst at America’s National Governors Association thinks there are ways to improve security dramatically, without the need to implement “exotic solutions” that rely on quantum computing or blockchain. It can be as simple as updating old software or mandating that election officials use physical authentication keys such as USB tokens to log into their computers, he says.

Meanwhile, Marian Schneider, president at non-profit organisation Verified Voting, advocates a multi-layered approach to securing elections. “You need various tools to protect assets,” she says – including monitoring devices, firewalls and the ability to recover information when something happens.

Most experts agree the answer to securing electronic voting machines involves a back-up option, just in case things do go wrong. And right now, the safest solution is a voter-verified paper ballot – a paper audit trail of all votes cast electronically. Online voting is a good idea in theory, but it also opens up more doors to attack and manipulate elections. In the future, that isn’t going to change, which leaves the onus on security experts to ensure they stay one step ahead of the hackers. 

HOW A WALL OF LAVA LAMPS IS HELPING TO SECURE ELECTIONS



Cloudflare is using lava lamps to create random numbers for the cryptography that underlies its election security offering. “When you visit a website and a lock appears on your browser, it’s there through a cryptographic process that exists by being able to generate a random number,” says Matthew Prince, the firm’s CEO and co-founder.

But computers are bad at the ‘randomness’ important in cryptography, he says. “If that number is predictable in some way, an attacker can undermine the cryptographic system itself.” To overcome this, Cloudflare uses physical solutions

doubling as art installations to generate random numbers.

In the San Francisco office, the installation is a wall of 100 lava lamps (below). “The movement of lava in the lamps is impossible to predict – it’s a chaotic system,” says Prince. “We film the lava lamps and any pixel that changes can be used as a source of randomness. We then feed this into the system generating random keys for all of Cloudflare’s network.”

In the London office they use a double pendulum. “Anything unpredictable can be a good source of randomness,” says Prince.

Kate O’Flaherty is a technology journalist that specialises in cybersecurity and telecoms. She tweets at @KateOfaherty





THE GREAT BRITISH BLAST OFF

The site has been chosen
and building will soon
begin on what will become
Britain's first spaceport.
Dr Stuart Clark looks into
exactly what we're likely
to be launching

If you were asked to think of the ideal site for launching rockets into space, chances are your first thought would be of Cape Canaveral in Florida, where NASA's famous moonshots began their epic journeys. Or possibly the similarly historic Russian site in Baikonur, Kazakhstan, where the launch of the world's first artificial satellite Sputnik 1 kick-started the space race and cosmonaut Yuri Gagarin blasted off to become the first human being in space. But chances are that Sutherland, a remote, rural county on the coast of northern Scotland, would be pretty far from your mind. But that is exactly the spot that the UK Space Agency (UKSA) has chosen to build the UK's first vertical-launch spaceport.

Look beyond first impressions, however, and it turns out Northern Scotland is actually a near-perfect location to build a spaceport. And being in the north it is ideally placed for launching satellites into polar orbit – an increasingly popular practice as this allows satellites to synchronise their orbits with the Sun so that the amount of shadows in any images they take are significantly reduced. Also, the Sutherland site has the added benefit that any rockets launched there would be able to fly straight over the sea rather than over populated areas where they may potentially cause problems.

The idea of placing a spaceport in Scotland dates back at least 15 years when it was suggested that the decommissioned Dounreay nuclear power plant in neighbouring Caithness would make the ideal location for a rocket launch pad. Plans for a



ABOVE:
Spaceport America in New Mexico was built to facilitate vertical and horizontal launches

LEFT: **A planning application to turn Sutherland, on Scotland's northern coast, into a spaceport is expected to be submitted in 2019**

Scottish spaceport were revived again in 2014 when the UKSA suggested the slightly altered location of the A'Mhoine peninsula, in Sutherland. But it wasn't until July this year that Business Secretary Greg Clark, announced that the government was stumping up £2.5 million to make the plans a reality.

If all goes to plan, Roy Kirk from Highlands and Islands Enterprise, who is leading the project, says the first launch from British soil will take place sometime in 2021. Early estimates suggest that the site will initially see somewhere between five to 10 launches a year but after that, it's anyone's guess. The UKSA has big plans for the site and hopes to secure a large chunk of the global space market by targeting an emerging technology: small satellites.

SMALL SATELLITES, BIG PLANS

"We have an ambitious target," says Claire Barcham, Commercial Space Director at the UKSA, "We want to capture 10 per cent of the global space economy by 2030. To do that the UK must become a thriving market for anyone who wants to launch a small satellite. Small satellites are transforming the economics around satellite services. They can do a lot more with a lot less."



**“If all goes to plan,
the first launch
from British soil will
take place in 2021”**

In certain circumstances small satellites are now capable of replacing large ones. Perhaps the key area where we will notice the small satellite revolution is in telecommunications. Traditionally communications satellites sit in a very high orbit – typically at 36,000km (22,300 miles) in a geostationary orbit – where they take 24 hours to complete a full rotation of the Earth and so appear to hover over the same spot. But, the distance for radio signals to travel up and down is large and creates a delay of about a quarter of a second that is noticeable and irritating. Small satellite constellations operating in low Earth orbit at around 500km (300 miles) in altitude will virtually eliminate this latency, improving long-distance communication for all of us.

And things are already happening. A company called OneWeb plans to use 900 small satellites to provide broadband access to remote locations. Another company, called Planet – which launched its first satellite in 2013 – intends to use a similar constellation of small satellites to provide highly accurate global imaging services. But these schemes aren't without their obstacles. As satellites get smaller, they have ironically become more difficult to launch because the existing rockets championed

by NASA, Russia and ESA are designed to hoist large satellites into orbit.

“It's the difference between a bus and a taxi,” says Barcham. A large rocket is rather like a bus, you have to wait for it to come along and then you crowd in with everyone else. A smaller rocket is like a taxi: a bespoke, individualised trip whenever you want it.

There are a number of small launchers now being developed by companies around the world that the UK Space Agency would like to attract to Sutherland. “They have the ability to transform how technology gets into space,” says Barcham. “We'd like to make sure that the UK is in the forefront.”

Of course, the satellites are only half of the picture. We will also need a means of getting them into space. This is where UK-based private launch specialist Orbex comes in. With £30 million already secured in public and private investment, the company is well on its way to developing a rocket that's perfect for launching small satellites.

“The company started as what the British would call a wheeze,” says Orbex CEO Chris Larmour. “Some friends and I were chatting over a beer one night and wondering how hard it was to build a ➤

“We want to capture 10 per cent of the of the global space economy”

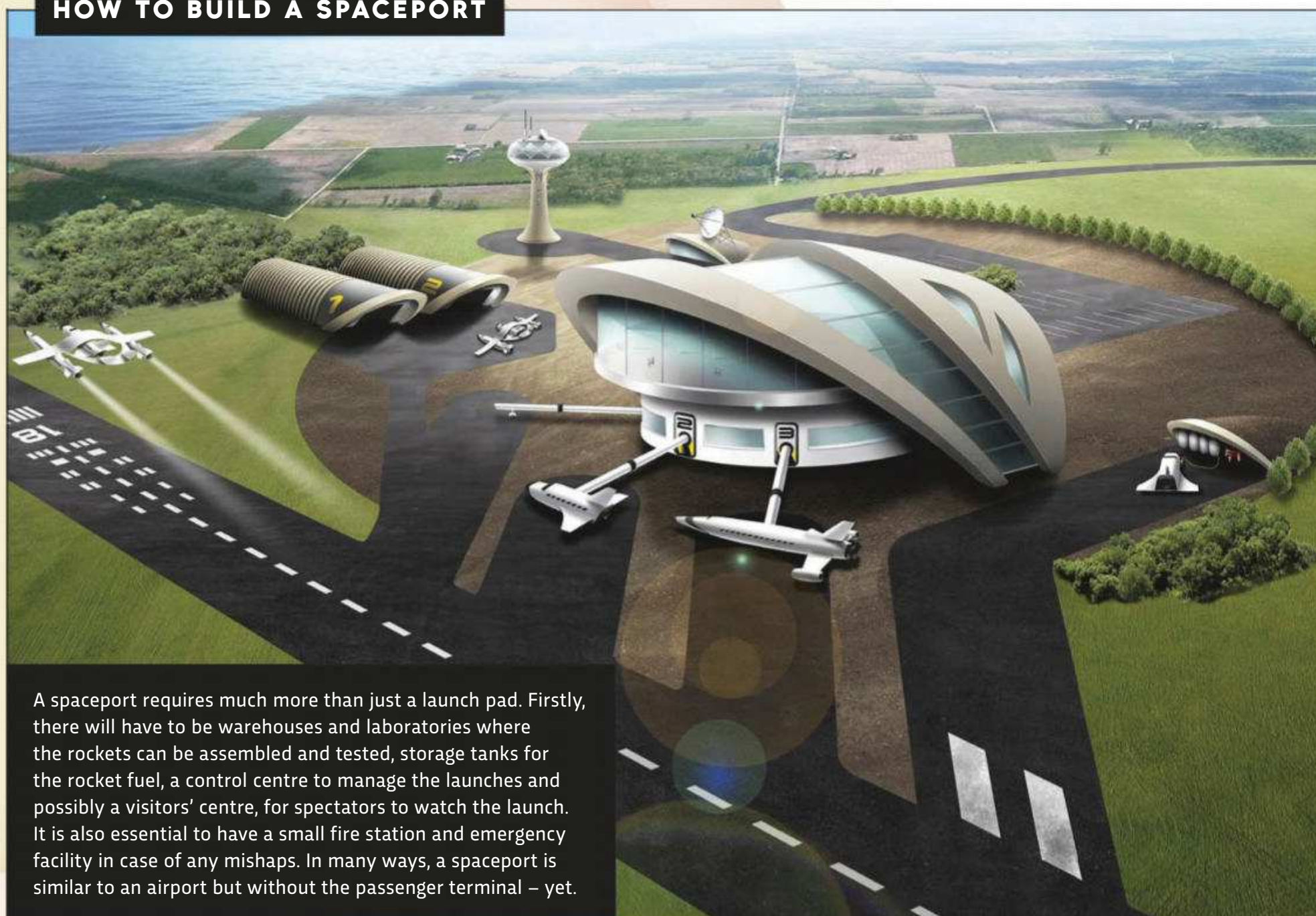
► Moon rocket in this day and age. We got to the point where it stopped being a wheeze and we realised it's potentially quite doable for a small company,” he says.

The rocket the Orbex team is developing stands around 17m tall, weighs in at 15 tonnes when fully fuelled and will be capable of delivering a payload of around 200kg into low Earth orbit, and placing it in position with an accuracy of 15m. It is also remarkably eco-friendly.

“A key driver for us is being a good tenant on the site,” says Larmour. To that end, his company has gone against convention and chosen to use propane as their rocket fuel. This is exactly the same fuel that the farmers and other inhabitants use in that area to run their homes. And the fuel tank of the Orbex rocket is roughly the size of a household tank that people have in their gardens. “We are no more destructive than one farm in that area,” says Larmour.

It is not just the launches, but the buildings and roads that will be needed, and the increase in visitors and staff that the spaceport will generate that needs to be considered. Kirk and colleagues are currently engaged in an exhaustive round of

HOW TO BUILD A SPACEPORT



A spaceport requires much more than just a launch pad. Firstly, there will have to be warehouses and laboratories where the rockets can be assembled and tested, storage tanks for the rocket fuel, a control centre to manage the launches and possibly a visitors' centre, for spectators to watch the launch. It is also essential to have a small fire station and emergency facility in case of any mishaps. In many ways, a spaceport is similar to an airport but without the passenger terminal – yet.



LEFT: Rocket Lab's Electron rocket is a suitable launch vehicle for commercial small satellites and has been successfully tested in New Zealand

public consultations with the inhabitants of the area to find the best solutions.

TO SPACE, VIA SCOTLAND, AMERICA AND NEW ZEALAND

As well as the start-up company Orbex, the Scottish government organisation Highlands and Islands Enterprise has also approached aerospace heavyweights Lockheed Martin only to find the American company was already thinking along similar lines. It had been investigating the possibilities of small satellite launches from the UK since the initial announcement in 2014 and had already identified a potential rocket, dubbed the Electron, being developed in New Zealand by a company called Rocket Labs.

"We are a strategic investor in Rocket Labs," says Patrick Wood, Head of UK Space for Lockheed Martin. "The Electron launch vehicle is an incredibly good, modular design." Electron is similar in size and capability to the Orbex launch vehicle, and has been launched twice already, performing flawlessly each time, with a further two launches scheduled before the end of the year. Once the rocket is ready for commercial use, Wood imagines starting launches at a rate of every month or two. ►

SPACE INDUSTRY STATISTICS

The current global space market is annually worth around

£250 billion

By 2030 the global space market is estimated to almost double its worth to around

£400 billion

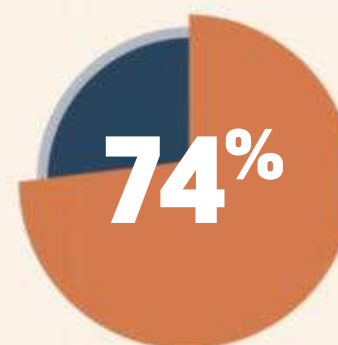
Currently, the UK space industry has a turnover of

£13.7 billion

– around 6 per cent of the global market. It aims to grow this figure to 10 per cent by 2030

Across the UK the space industry employs more than

38,000



of the turnover of the current UK space industry comes from satellite applications

£2.5 million

The amount the UK government is proposing to invest in the Sutherland spaceport



“We would aim to do 6-10 launches a year from Scotland. Those launches may have anything from one to six satellites on them,” says Wood. “Our goal would be to grow that number over time. This is about growing an industry and stimulating growth. We want to increase the number of apprentices and graduates who come into this industry.”

There is no doubt that satellites and their uses are changing rapidly, and that that change will bring with it the need to access space more frequently and easily. With this in mind, the UKSA is preparing to play the long game. Plans are already underway for potential other launch sites in Cornwall, Glasgow and North Wales, though these would be horizontal launch sites rather than vertical one planned for Sutherland. Vertical launch sites are traditional launch pads where the rockets travel directly up in a straight line. Horizontal launch pads are essentially beefed-up airport runways.

A launch from a horizontal pad relies on a rocket being strapped onto the fuselage or wings of a conventional aeroplane. The plane lifts off and then the rocket it's carrying detaches, ignites and completes its flight to orbit once the plane has reached a certain altitude. In the future, it's also possible that actual

ABOVE: **Rocket Lab** has been testing its **Electron** launch vehicle at **Launch Complex 1**, its private orbital launch site in **Mahia, New Zealand**

INSET: The standardised dimensions of the 'CubeSat' nanosatellites makes them an ideal payload to be launched from a UK site

ROCKET LAB / NASA


spaceplanes that are capable of 'flying' into orbit themselves could use these runways. One thing is certain, whether vertical or horizontal launches take precedent, the government is determined to make the UK a major player in space access.

“Our vision is to encourage companies to use the UK for launch. It will place us at the cutting edge of the space sector,” says Barcham.

T MINUS THREE YEARS AND COUNTING...

Once the public consultations are finished, Kirk envisages lodging a planning application before the end of 2019 and then starting to build in 2020.

“We are doing lots of preparatory work. Then we will move quickly once all the consents are in place, and the community is behind it,” says Kirk. “We want to make sure the area gets the maximum benefit out of hosting the site.”

With the maiden launch from Sutherland potentially less than three years away, the countdown to the great British blast off has begun. 

Dr Stuart Clark's latest book is *The Search for Earth's Twin* (Quercus). [@DrStuClark](http://www.stuartclark.com)

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FOCUS

SCIENCE OF SOUND

YOUR GUIDE TO THE LATEST IN CUTTING-EDGE AUDIO EQUIPMENT



ELITE SOUND

Elite Audio presents the innovative s1 speaker from Germany's Manger Audio



available in the UK exclusively through Elite Audio, Manger Audio's s1 active two-way floorstanding loudspeakers are the culmination of over 45 years of experience in high-end audio engineering.

Manger Audio was set up in Germany by Josef W. Manger in the late 1960s and is now owned and run by his daughter Daniela, an electrical engineer who has been responsible for all speaker developments for more than two decades. Disenchanted with the sound quality of speakers that were available at the time, Josef decided a whole new approach was needed. He realised that a conventional speaker principle stores energy and creates its own spatial and tonal footprint. His research brought him to the bending wave principle, that reflects the way the human ear actually processes sound. Several years of painstaking research led him to develop the technology that lies at the heart of all Manger speakers: the Manger Sound Transducer.

Simply put, most loudspeakers – whatever the

price tag – work the same way. A magnet and moving coil arrangement causes a cone to vibrate and store energy. Manger speakers, on the other hand, have no cone: instead, they're based around the flat membrane of the Manger Sound Transducer. This, too, features a magnet and coil arrangement, but instead of causing a cone to move backwards and forwards, in this case it's used to send radial waves through the flexible membrane of the transducer itself, just like the ripples that emanate outwards when you throw a stone into a pond, precisely like the incoming signal.

The transducer membrane is made up of three layers, and its rigidity varies across its diameter, which means different sound frequencies propagate through it differently – just as they do inside the

“Manger speakers are much better than more orthodox systems at reproducing ‘transient’ sounds”

basilar membrane in the human ear. Low frequency sounds ripple right across the entire membrane, before reaching the star-shaped damping mechanism around the edge of the diaphragm, which prevents them from reflecting back towards the centre and thus eliminates any problems caused by constructive or destructive interference between the outgoing and reflected waves. Higher-pitched sounds, on the other hand, ripple only through the central part of the membrane.

There are several benefits to such a system – most notably when it comes to timing. As the Manger technology doesn't rely on physically getting a large, comparatively rigid membrane (the traditional speaker cone) to move, Manger speakers are much better than more orthodox systems at reproducing 'transient' sounds – sounds which occur for only a fraction of a millisecond, as opposed to long, sustained musical notes. They're therefore able to offer up a truer representation of the incoming audio signal, capturing those tiny nuances that cone-based speakers are likely to miss.

Secondly, from an engineering point of view, the construction of the Manger Sound Transducer eliminates the need to have separate low, middle and high frequency cones as in a traditional loudspeaker, with just one transducer covering almost the full audio range. s1 gives you the best of both worlds, with the Manger Sound Transducer taking care



THE RANGE

Manger Audio W1
on-wall speaker
£4,182

Manger Audio Z1
compact speaker
£6,546

Manger Audio P1
loudspeaker
£8,571

Manger Audio P2
loudspeaker
£11,429

Manger Audio C1
active two-way speaker
£11,454

Manger Audio S1
active two-way
floorstanding speaker
from £14,546

of everything from 360Hz up to 45000Hz, and a 200mm glass fibre/polyester cone handling bass frequencies down to 30Hz.

Inside each 48kg s1 speaker are two discrete Class AB amplifiers – a 250W amp drives the bass cone, while a 180W amp powers the Manger Sound Transducer. Reflecting Manger's philosophy that its speakers should be accurate enough for use as studio monitors as well as for home hi-fi listening, there are also a range of sound-shaping controls mounted on the rear panel: an 11-position +/-2.5dB input trim switch, a +/-6dB input sensitivity control, plus EQ controls in the 100Hz, 3.25kHz and 10kHz wavebands, which means even the most demanding listener should be able to tweak the sound coming out of the speakers to match the acoustics of their listening environment perfectly.

And if that's not enough control for you, like all Manger speakers, the s1 is available in just about any colour you can imagine! Manger (and Elite) can match any colour from the RAL or NCS colour palettes in a satin or ultra high gloss (RAL only) finish for the perfect integration in your living area.

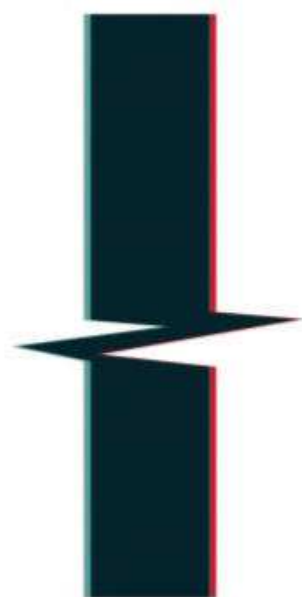
Manger produces the drivers and speakers completely in-house, while tolerances like watchmaker are the base for these unique products. The s1 retails for £14,546 to £16,364 depending on your choice of finish. But if natural sound is what matters, then contact Elite Audio to arrange an in-store demo or a no-risk, 30-day home trial.



TO FIND OUT MORE
visit eliteaudiouk.com
and mangeraudio.com



British sound innovator Flare Audio continues to push sound-quality barriers with the launch of its affordable Flares® JET earphones



It was only a year ago that audiophiles were blown away when Flare launched its award-winning Flares® Pro and Flares® GOLD earphones. Top musicians and producers were quick to sing their praises, including classical pianist James Rhodes, Grammy award-winning producer Tony Visconti and Julian Lennon.

Now this innovative UK company is back, bringing its pure sound to a wider audience with the new lower-priced Flares® JET earphones - and listening is believing. These tiny earbuds deliver the deepest bass, total clarity and multiple layers of sound, uncovering subtleties you've never heard before in your favourite tracks. Forget listening in black and white - this is listening in full colour.

Described by Flare as 'X-ray hearing', Flares® JET earphones contain revolutionary patent-pending technology that uses jets to control and focus sound directly into

THE RANGE



Flares® JET 1
Polymer RRP £49



Flares® JET 2
Aluminium RRP £69



Flares® JET 3
Titanium RRP £89

“They’re easily the best in-ear earphones I’ve ever used. Lovely bottom end, beautiful depth and clarity to the overall sound”

Pete Paphides, DJ and Music Journalist for Melody Maker, The Guardian, Time Out and Q Magazine

your ears. This, combined with superb isolation and reduced distortion, gives the best sound wherever you are.

Flares® JET earphones are available in three models - Jet 1 Polymer, Jet 2 Aluminium and Jet 3 Titanium - and you can try them out risk-free with Flare's 30-day money back guarantee. Maybe it's time to wake up and hear the music?

TO FIND OUT MORE
visit flareaudio.com





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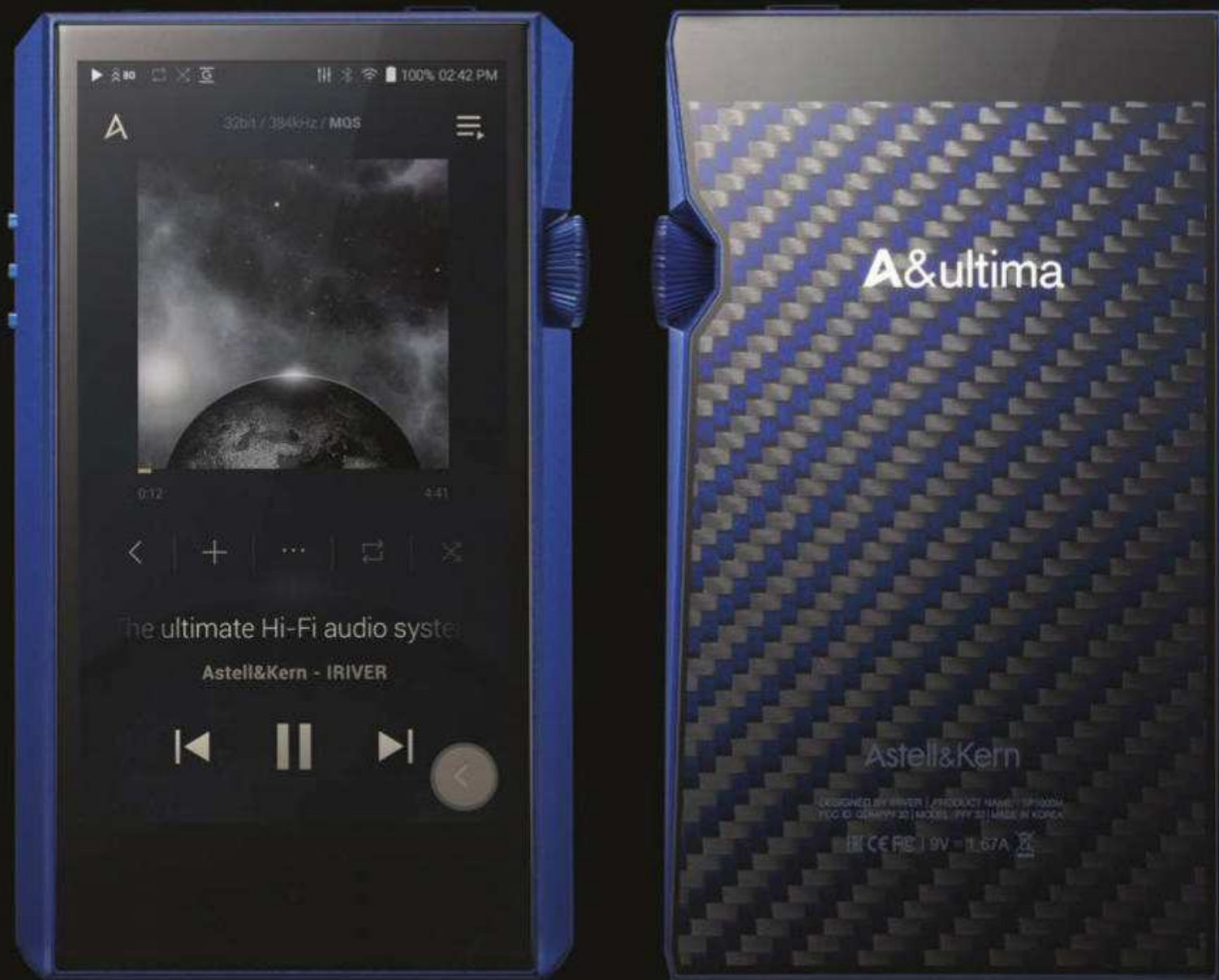
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HI-FI RE-IMAGINED

Stream high-quality audio with DALI's CALLISTO range



While Bluetooth speakers are certainly convenient, the sound quality they offer isn't always the best. That's something DALI is seeking to rectify with its new CALLISTO range, which lets you stream high-quality 24-bit/96kHz audio - bringing you the convenience of streaming without the compromises, and audiophile sound without the wires.

At the heart of the system sits the DALI Sound Hub, which will accept a wide variety of analogue and digital inputs: RCA phono, 3.5mm jack ('Aux'), digital optical, digital coaxial and, most importantly, streamed audio. Here you have two options. DALI recommends that you add the optional BluOS expansion module - which brings compatibility with BlueSound's audiophile-quality multi-room platform, and allows you to stream services like Spotify and Tidal in high resolution - but standard Bluetooth streaming is also available, using the AAC, Apt X or Apt X HD protocols (which means it's compatible with all smartphones and computer systems). In either case, everything's controllable direct from your smartphone or tablet, while the two expansion ports enable you to install additional sound modules offering multi-channel audio and more.

From there, your music is relayed wirelessly to the speakers. The CALLISTO line-up includes both floorstanding and bookshelf speakers - the CALLISTO 6 C and 2 C, respectively - but both pack dual 250W Class D amplifiers in each speaker, which means you're certainly not going to be found wanting in the volume department! Both models also feature DALI's innovative SMC (soft magnetic compound) technology in the drivers, delivering greatly limited distortion from the low-mass CALLISTO wood-fibre bass cones.

In short, if sound quality is important to you but you want the convenience of a wireless system, contacting your nearest DALI dealer and arranging to hear the CALLISTO range in action for yourself is highly recommended.

THE RANGE

Dali Callisto 6 C
£3,199/pair

Dali Callisto 2 C
£2,399/pair

Dali Sound Hub
£549 with optional
BluOs module at £459



TO FIND OUT MORE
visit dali-loudspeakers.com

USED BY THE PROS

When top-flight musicians need a DAC they can count on, they turn to AudioQuest's Dragonfly Red

P

erhaps best-known for his work as a member of Ace, Squeeze and Mike + The Mechanics, keyboard player and vocalist Paul Carrack has also toured and recorded with Roxy Music, The Pretenders, BB King, Madness, Simply Red, The Smiths and Elton John, to name

but a few. Most recently he found himself touring with Eric Clapton, which presented something of a problem, because he was also working on his latest solo album with the esteemed producer (and former Mechanics bandmate) Peter Van Hooke.

This meant that the pair needed to be able to compare notes remotely while Carrack was on tour, so they needed to be able to swap ideas, mixes and edits back and forth, confident that they were both hearing exactly the same thing. The answer was provided by technology: take two identical laptops, two identical sets of headphones, and two identical AudioQuest Dragonfly Red headphone amp/DACs.

The original, USB-sized Dragonfly DAC caused a massive stir when it hit the market in 2012, and in 2016 AudioQuest introduced the premium Dragonfly Red model, which as well as adding compatibility with iOS and Android devices, also boasts an improved ESS Sabre 9016 32-bit DAC chip and a boosted output voltage.

"The AudioQuest DragonFly was a revelation," enthuses Carrack, "helping us hear every musical detail with such a natural tonality. It was so fun and easy to use, it really streamlined our creative process and enhanced our ability to communicate and make music that we are proud of. I simply don't want to be without it!"

You don't need to be an internationally acclaimed musician to feel the benefit, though – all you need is a pair of ears, and even if you're just listening on your daily commute, you'll be amazed how much difference a tiny piece of kit can make.

AudioQuest and its retailers will be holding events to celebrate the album and tour, giving you the chance to win show tickets, DragonFly DACs, signed albums and more.

THE GADGET



Dragonfly Red
£169

"The AudioQuest DragonFly was a revelation helping us hear every musical detail with such a natural tonality"

Paul Carrack, keyboard player and vocalist as a member of Ace, Squeeze and Mike + The Mechanics

audioquest.

TO FIND OUT MORE about Paul, the recording of the album, and the events being run please visit bit.ly/AudioQuest



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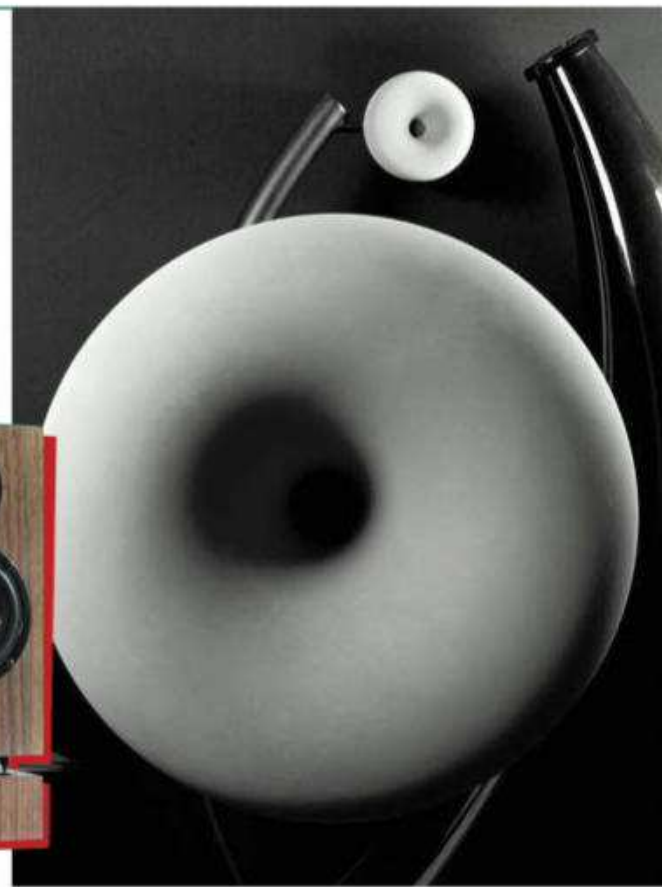
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BACK TO THE FUTURE

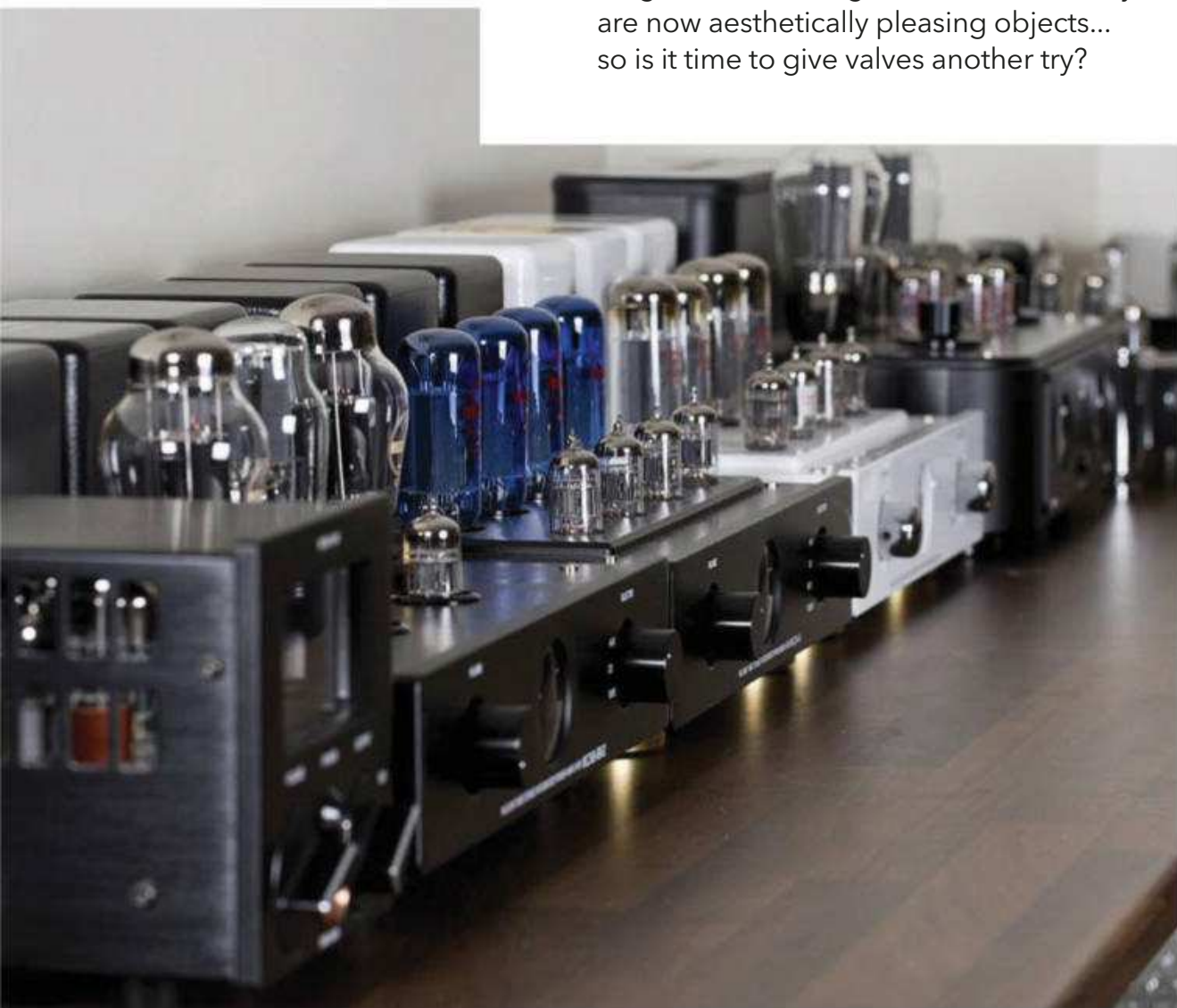
Malvern Audio Research's products combine valves and state-of-the-art technology for the ultimate listening experience



When transistors first found their way into mass-produced electronics equipment in the 1960s, they kick-started a revolution in hi-fi technology. Transistor-based amplifiers were sleek, compact and more powerful than the valve amps that had gone before them – and have represented the overwhelming majority of amplifiers sold ever since. But some 50 years later, valve technology has moved on apace. Modern Valves amplifiers are far more reliable, no longer hidden in big wooden boxes, they are now aesthetically pleasing objects... so is it time to give valves another try?

Valve amps are famous for their warm, natural sound – and for good reason. The typical transistor-based amplifier uses up to 50 individual transistor circuits to amplify your audio signal, whereas the typical valve amp will be using just three to five amplifying components. Each individual stage of the amplification process inevitably adds a certain colouration to the sound signal. Known technically as 'intermodulation distortion', the effect is for individual sounds to become mashed together. So it doesn't take a genius to work out that an amp with far fewer devices is going to produce a clearer, less muddled signal – resulting in that warm, natural sound we talked about.

Malvern Audio Research is led by a team of audio engineers who actually hand-built their own pre-amplifiers, power amplifiers and phono stages, offering a deep working knowledge to achieve the best possible results. The company also sells, a selection of quality, hand built artisan cables, loudspeakers, turntables and other valve amplifiers, to enhance your listening experience. If you're serious about sound quality, why not contact their showrooms and arrange to give some of their products a listen? You might find a blast from the past is just what your ears have been waiting for!



TO FIND OUT MORE
visit malvernaudioresearch.co.uk



THE RANGE



Audio Pro A40
£900



Audio Pro A10
£180

SWEDEN'S REAL ACES OF BASS

Audio Pro celebrates 40 years in the hi-fi game with two new speakers



In 1978, a Swedish tech start-up – yes, they had tech start-ups in the '70s, too! – called Audio Pro patented a new technology called ACE-BASS, which made it possible to build small speakers that still offered plenty of low-end grunt. That technology has informed every product it has made since, and it's served the company well.

This year sees Audio Pro celebrating its 40th anniversary, and it's marking the occasion with a brace of new loudspeakers that return to that original ethos of providing big, hefty

bass – but now in the context of modern streaming technology. Both will be in stores before Christmas.

The flagship of the range is the A40. Its name a nod to the company's original A4.14 speaker, the A40 is a compact streaming speaker that Audio Pro says is designed to offer a "big, open, spacious, full-bodied sound covering the full frequency range of a traditional speaker of maybe 10 times the size". It's a single-unit, full-range speaker – which will

help keep clutter in your living room to a minimum – and supports the streaming of lossless audio in all popular file formats, so there's no need to compromise on sound quality.

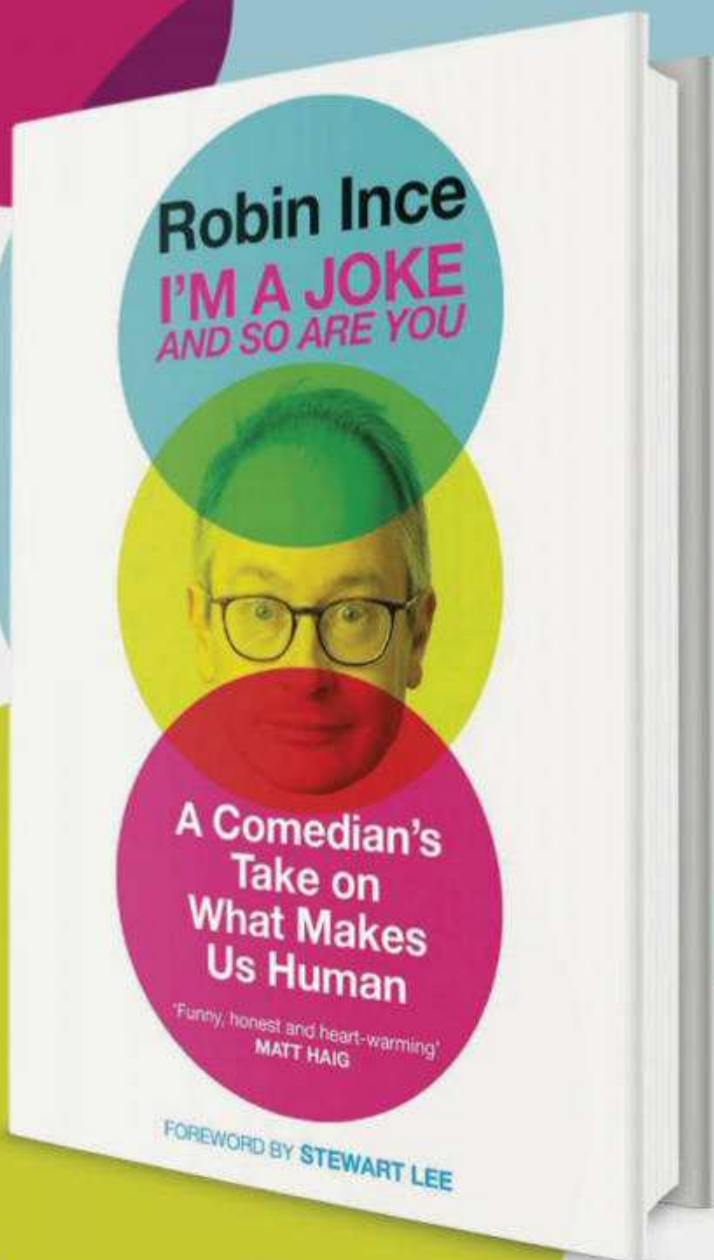
The other new speaker is the A10, which is something of a departure for Audio Pro in design terms: it's round, for a start, and it's grey. Audio Pro tells us "the idea is to provide the market with speakers that are designed to fit the different needs and designs of different rooms," but don't worry – inside the box is the same high-quality circuitry you'll find in its bigger brother.

What's more, like all of Audio Pro's recent products, the A40 and A10 are built to be multi-room compatible, so you can mix and match them with speakers from the C and D ranges to create a multi-room system that's perfectly matched to the size and the decor of every room in the house.

 **audio pro**

TO FIND OUT MORE

visit audiopro.com | Distributed by Hama UK



Where does anxiety come from? What is the key to creativity? How can we deal with grief?

Robin Ince, comedian and co-presenter of *The Infinite Monkey Cage* explores the fascinating (and often hilarious) mysteries of the human mind.

'Funny, honest and heart-warming.'

Matt Haig

'Deceptively deep. Invaluable and inspiring.'

Stewart Lee

'Clever, witty and wise.'

Claudia Hammond, presenter of BBC Radio 4's *All in the Mind*

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These miniature 3cc V-Twin combustion engines run off butane or propane gas. They are small enough to run on your desk and have an awesome v-twin sound. Just turn the valve and flick the flywheel to get it started.



This Vulcan stove fan is driven using Stirling engine technology using just the heat from a stove. It requires no external power source such as batteries or AC power. The fan circulates the stove's warmth quietly, efficiently and inexpensively.



Newly invented, this tractor beam magnet contains a number of magnets in a special arrangement. The special arrangement creates a unique magnetic field that can hold another magnet a fixed distance away.



First you notice that it is levitating, then you notice it is spinning using just the power from the sunlight! Ultra-strong neodymium magnets keep it levitating, while more magnets and copper coils and solar panels keep it rotating.



A very interesting simple and fun toy. When the lower portion of the glass sculpture is held, the liquid rushes into the upper section, and appears to boil furiously. Then hold the top section and liquid returns to the bottom.



Ferrofluid is a runny fluid that is magnetic. Hold a magnet to it and watch how it reacts. Some of the shapes you are can create are mesmerizing.



DR ALASTAIR GUNN
Astronomer,
astrophysicist



ALEX FRANKLIN-CHEUNG
Environment/
climate expert



DR PETER J BENTLEY
Computer
scientist, author



PROF ALICE GREGORY
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sleep expert



PROF MARK LORCH
Chemist,
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conservationist



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DR GILES YEO
Geneticist and
diet expert



PROF ROBERT MATTHEWS
Physicist,
science writer

YOUR QUESTIONS ANSWERED

NOVEMBER 2018

EDITED BY JAMES LLOYD

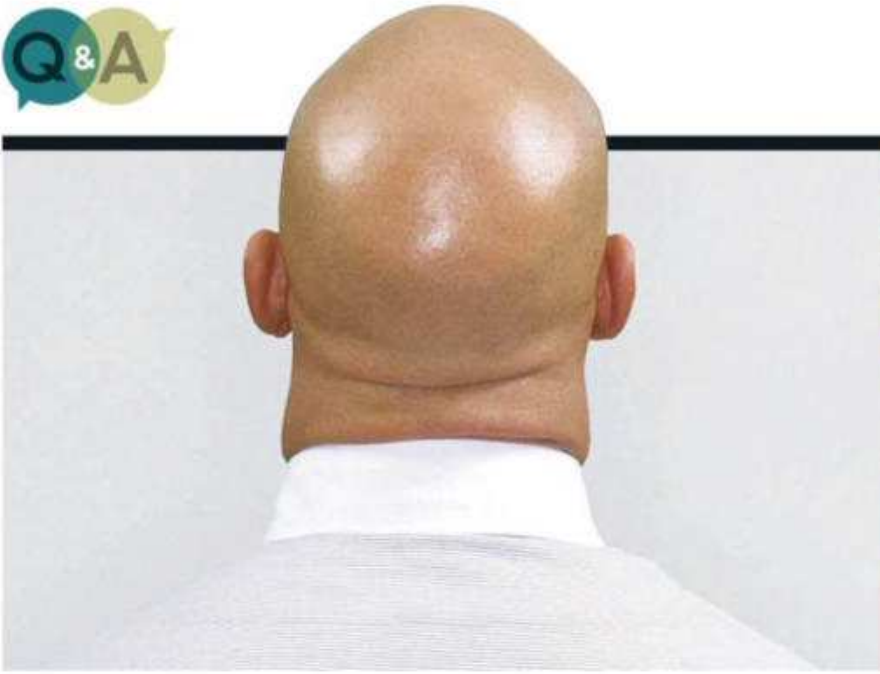
Why aren't large Lego bricks used to build full-size buildings?

EDWARD SEYMOUR, HOVE

The plastic used in Lego – a type of polymer called ‘acrylonitrile butadiene styrene’ (ABS) – is surprisingly strong. In fact, it’s able to withstand compression better than concrete. Researchers at the Open University in 2012 found that an ordinary-sized Lego brick can support the weight of 375,000 other bricks before it fails. Theoretically, that would allow you to build a tower almost 3.5km high! But Lego is far too expensive to be used as a large-scale

building material. There are, however, Lego-style construction techniques that use other materials. ‘Insulated concrete formwork’ (ICF) uses hollow polystyrene blocks that are assembled into walls and then pumped full of concrete. The polystyrene acts as a mould and provides insulation. And in developing countries, interlocking blocks of compressed earth mixed with a small amount of cement are used as a cheap alternative to bricks and mortar. **LV**





Why are bald heads so shiny, when the skin elsewhere on your body isn't?

DAVE JEFFERIES, BARROW-IN-FURNESS

Most of the skin on your body is actually covered with tiny hairs called vellus hairs that give your skin a slightly velvety, peach-fuzz look. With male pattern baldness, the hair follicles shrink and turn into skin cells, so there are no hairs at all – not even vellus hairs. But the scalp is particularly shiny because of the sebaceous glands. These secrete oil and are found all over our skin, but the scalp has a lot more and this oil coats the skin and provides a more uniform reflective surface. What's more, studies suggest that more active sebaceous glands could actually play a role in early hair loss. **LV**



Is there any objective evidence of more bad luck on Friday the 13th?

TONY HERSH, NEWBURY

In 2017, a study of US fatal car crash statistics suggested that Friday the 13th has around 12 per cent more incidents than average. There have also been claims that Fridays generally are worse for hospital operations. But given the countless things that can go wrong, clearly some will turn out by chance to be more common on Friday the 13th. Plus, when they do, many people will see it as 'proof' of their superstition. **RM**



Why does the Earth spin?

OLUWALANA COVENANT, AGO IWOYE, NIGERIA

The Solar System formed almost five billion years ago from a turbulent cloud of gas and dust. The motions of the atoms and molecules in that cloud were extremely unlikely to average out to be exactly zero. In essence, there would have been a tendency for them to move, or rotate, in a certain direction. As the cloud collapsed under gravity, the conservation of angular momentum ensured that the cloud's initial rotation was magnified, eventually flattening it out into a disc. The Earth formed within that disc and spins because it inherited its angular momentum from its 'parent' cloud. **AGu**



When trees grow, where does the matter come from?

TOBY GRAHAM, SHREWSBURY

Trees get their matter from the carbon dioxide in the air, and the water they take in through their roots, with just a small amount of nutrients coming from the soil itself. During photosynthesis, trees use the Sun's energy to break apart the carbon dioxide (CO_2) and water (H_2O) molecules to form glucose ($\text{C}_6\text{H}_{12}\text{O}_6$) and oxygen (O_2). Some of this glucose is used to respire, while the rest goes into forming cellulose, the primary building block for new branches, stems, leaves and roots. **AFC**

...I BURP AND FART?

Everybody burps and farts around 2.5 litres of gas per day, which comes from the air we breathe, the drinks we quaff and the bacteria in our digestive system. Our bodies get rid of this excess gas via the mouth and anus. Unlike cows, methane is not a major constituent of our farts. So if someone sets a fart alight, it's usually hydrogen gas that's burning.

BURPING



1. Eat and drink

With every mouthful of food or drink, you swallow a couple of millilitres of air – mostly nitrogen and oxygen. Carbonated drinks also add another millilitre or so of carbon dioxide.



2. Gases separate

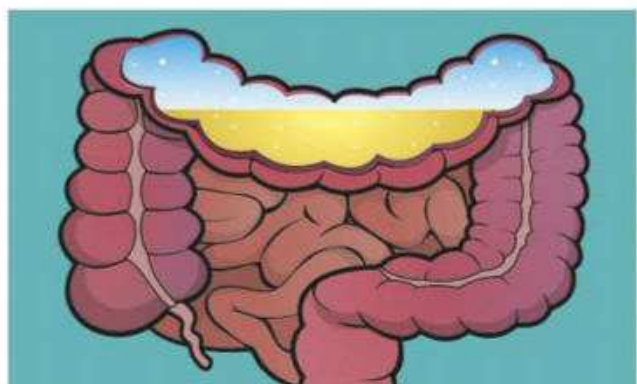
The gases separate from the food in your stomach and press against the lower oesophageal sphincter, which holds the top of the stomach closed.



3. Sphincter opens

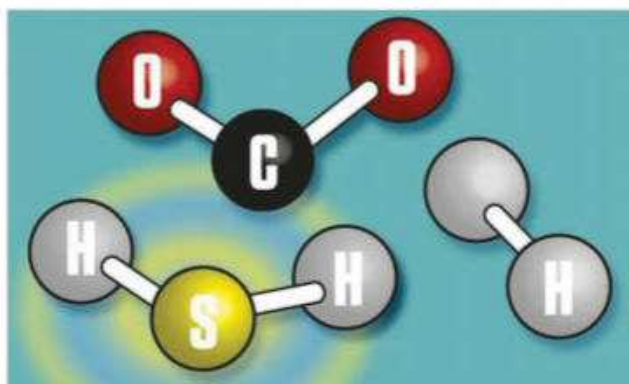
Eventually, the pressure forces the sphincter open and the air rushes out. The belching sound is caused by vibrations in the sphincter and oesophagus wall.

FARTING



1. Bacterial action

A small amount of swallowed air makes it into the intestines, but most of the gas there is produced by the bacteria that help to digest our food.



2. Stinky sulphur

The gas is mainly hydrogen and carbon dioxide. The smell comes from sulphur compounds that are only present in trace amounts.



3. Fart or poo?

The nerve endings in your anus allow you to distinguish between a build-up of gas and a solid stool, so you can pass wind safely.



Why do some people get earworms more than others?

ELLY FENLON, LONDON

Surveys have revealed that the more important a person considers music, the more likely they are to experience earworms (catchy songs that play repeatedly through your mind). Psychologists consider earworms to be a specific kind of 'involuntary memory', so these associations make sense – the more you think about, practise, or listen to music, the more chance that memories of those experiences will spring to mind of their own accord. Personality is another relevant factor, with people high in the trait of open-mindedness being more prone to earworms (this is understandable given that this trait correlates with time spent listening to music). Another study found that people with less mental control were no more likely to experience earworms, although they did find them more disruptive and harder to stop. **q**

IN NUMBERS

600

The length, in metres, of a floating barrier launched into the Pacific Ocean by Ocean Cleanup. It aims to collect five tonnes of debris a month.

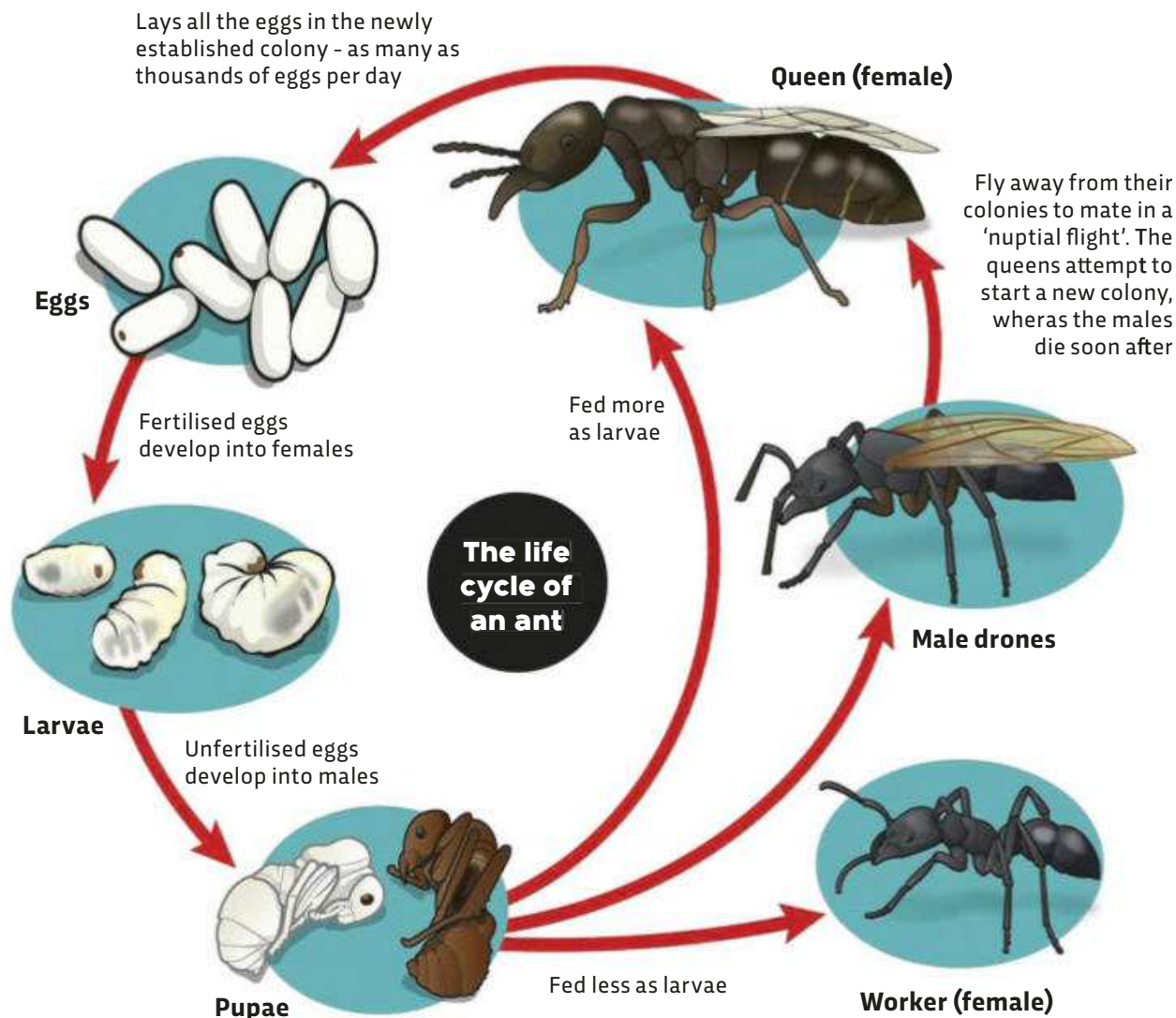
0

The number of Spix's macaws left in the wild, according to new data from Birdlife International.

Why do some ants have wings?

TERRY CROFT, SLOUGH

The ants you normally see scurrying around the garden are wingless females. They do all the work of the colony, but they are sterile. The flying ants are the male drones and virgin queens that are produced by the colony, once a year. These are sent out en masse, when the weather conditions are right, to start new colonies. **LV**



Why does time seem to go slower when we're bored?

CHRIS MOORE, ANDOVER

Although we feel sluggish and tired when we're bored, at a physiological level it's actually a 'high arousal' state (as measured by a faster heart rate). In turn, it's well-established that greater arousal speeds up our brain's 'internal clock', so that we feel that more time has passed than actually has. Another theory is that the apparent slowing down of time is a kind of signal our brain sends to itself to convey that the current situation is unfulfilling and we should do something else. **CJ**

Do platypuses really sweat milk?

JENNY PETERSON, ELLESMERE PORT

They secrete milk from specialised mammary glands, just like humans and other mammals. But platypuses don't have teats, so the milk just oozes from the surface of their skin. This makes it look like sweat, but in fact platypuses are aquatic and don't produce regular sweat at all. Since this delivery system is less hygienic than the direct nipple-in-mouth method, platypus milk contains powerful antibacterial proteins to protect the babies from illness. These proteins may be a useful source of future antibiotics. **LV**

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Is MSG bad for you?

ERICA EVANS, WORTHING

MSG, or monosodium glutamate, certainly has a bad reputation, conjuring up images of takeaways and highly processed foods. But this ‘umami’ flavour enhancer – first extracted from seaweed in 1908 – contains only sodium (one of the ingredients of common table salt) and glutamic acid, which is naturally found in foods such as mushrooms, tomatoes and Parmesan cheese. A popular belief is that MSG can cause headaches and a generally ‘icky’ feeling known as ‘Chinese restaurant syndrome’. But this is a myth: scientists have found no evidence linking typical MSG amounts to headaches, or any other health problems for that matter. Just like salt, a sensible amount is perfectly safe, and tasty too. **GV**

Why didn't the Big Bang produce equal amounts of matter and antimatter?

ADAM KING, HUDDERSFIELD

This is one of the biggest mysteries about our Universe, and solving it may spark a revolution in physics. According to current theories, the Big Bang triggered the creation of pairs of particles and antiparticles, their mass coming from the intense radiation of their surroundings according to Einstein's famous equation $E = mc^2$. But as the Universe cooled, this process stopped – and something odd happened. The pairs of particles and antiparticles should have simply re-combined and turned back into energy. Yet while the vast majority did that, for every billion pairs that vanished, one left behind a single particle – and it was always a particle of matter.

We owe our very existence to this anomaly, but explaining it has proved extremely difficult. That's because while antimatter and matter are radically different in many ways, the slight imbalance needed to explain today's Universe points to a difference which is very subtle indeed.

The quest for answers has recently focused on particles called sterile neutrinos and antineutrinos. Theorists think that these may be different in ways capable of explaining why there's more matter than antimatter. In May this year, researchers in the US claimed to have found evidence for the existence of these particles, but this has yet to be confirmed. **RM**

Platypuses
can remain
submerged
underwater for a
minute or two,
using their
sensitive bills to
search for food

WHO REALLY INVENTED?

THE
FLUSHING
TOILETSIR JOHN
HARINGTONTHOMAS
CRAPPER

This question always raises a smile among those who know the answer – or at least, think they do. That's because the invention of what is often rated as one of the most important contributions to human health is often attributed to a Victorian plumber named Thomas Crapper.

Crapper certainly existed, and he was an innovator, patenting the U-bend and floating ballcock – key parts of the modern toilet. Commercially, he also did much to encourage the installation of handbasins alongside toilets. As such, Crapper does have a claim to have invented the lavatory, which is the term for a room combining the two.

But Crapper did not invent the flushing toilet. The basic idea of using water to wash away sewage dates back to the Bronze Age. Around 4,000 years ago, cities in the Indus Valley had sophisticated sanitation – including communal toilets flushed with running water.

Credit for inventing the forerunner of the device we're familiar with today generally goes to the Elizabethan courtier Sir John Harington in 1596. Known as a water closet, it was installed in Richmond Palace. Yet despite this royal support, the device was long rejected by the public, who saw it as an expensive indulgence. **RM**



Does a hot summer trigger an early autumn?

ANTHONY JONES, SWANSEA

Fruits and berries that we normally associate with autumn can ripen early during a hot summer. But there are other autumnal changes that are unaffected or even slowed by a long, hot summer. Leaves won't lose their green colour

until the nights start to get chilly, because cold temperatures are needed to break down the chlorophyll pigment. Also, birds decide when to migrate south for the winter by the shortening day length, not the weather. **LV**

Why do high-voltage
power lines crackle
and hiss?

RICHARD LINDLEY, WINCHESTER


It's primarily the effect of the high voltage on the air surrounding the cable. Air is normally a very poor conductor of electricity. But if a sufficiently high voltage is applied across a small distance, electrons from the air molecules are stripped off and start to form a current. This in turn causes intense heating of the air – resulting in crackle and hiss. It's most common during damp weather, when the air becomes a better electrical conductor. **RM**

Why do we get blisters?

PAUL LAYFIELD, VIA EMAIL



Blisters are one of the skin's ways of protecting itself from harm, such as excessive friction (new shoes that rub), burns, irritating substances or allergies. Fluid collects between the outermost skin layer – the epidermis – and the layer below – the dermis – which are usually firmly connected. This bubble of fluid, most often a clear liquid called 'serum', shields the skin structures below from further damage, allowing healing. So as tempting as it is, it's best not to pop a blister. **ZW**



WHAT IS THIS?

Australian crater

In this false-colour image taken by the Copernicus Sentinel-2A satellite, we can see the Gosses Bluff crater in Australia's Northern Territory. The crater is visible in the left centre of the image and is about 22km in diameter. It was most likely formed 140 million years ago by the impact of a large comet or meteorite slamming into the surface of Earth.

WHAT'S THE POINT OF LAUGHTER?

We teamed up with the folks behind BBC World Service's *CrowdScience* to answer your questions on one topic. You can tune in to *CrowdScience* every Friday evening on BBC World Service, or catch up online at bbcworldservice.com/crowdscience

Why do we laugh?

Laughter is packed with information. We use laughter to show others that we're being playful and non-threatening, and this serves to make and maintain social bonds. Much of the time laughter is involuntary and contagious, particularly between friends. The sound of laughter broadcasts loudly and widely, so that other people outside of the laughing group can get information about the relationship of the laughers. In fact, Dr Greg Bryant at University of California, Los Angeles, has found that we're so adept at interpreting laughter that, in over 20 cultures, people can usually tell from just one second of laughter whether the laughers are friends or strangers.

Which came first, language or laughter?

Most anthropologists think that language originated within the last few hundred thousand years, but it looks like we've been laughing for much longer. In 2009, psychologist Dr Marina Davila-Ross at the University of Portsmouth recorded the vocalisations of baby ape species while they were being tickled. By analysing their sounds, she found that great ape laughs share the same structure as human laughs, and that these are most similar in the chimpanzees and bonobos, our closest animal relatives. Her work suggests that laughter arose from a common primate ancestor millions of years ago – long before language evolved.



Why does tickling make us laugh?

Laughter is most often associated with pleasure, but, for many people, tickling brings with it a certain amount of pain. So laughing when being tickled is a rather odd response, especially when you consider that tickling has historically been used as a form of torture. Prof Sophie Scott, a neuroscientist and laughter expert at University College London, believes that the laughing response evolved in mammals as a form of social bonding. It's a way for parents to bond with their children, and for children to play and compete without being hurt. As well as great apes, we also find social laughter in rats – they make high-pitched squeaking noises when being tickled, particularly the younger rats.



Rory Galloway is the producer of *What's The Point Of Laughter?* – an episode of *CrowdScience* that can be streamed at bbcworldservice.com/crowdscience

HOW IT WORKS

FIREWORKS

It's November, which means the skies are full of sound and colour. The large aerial fireworks are either rockets, like the one shown here, or mortars. Both are packed with exploding shells, known as 'stars', that are launched into the air using gunpowder. Mortars propel the payload upwards with a single explosion, whereas a rocket is propelled by a slower burning charge that provides gentler acceleration, for longer.

1 Electrical igniter

Commercial fireworks are often synchronised with music, so the fireworks are triggered via signals sent through electrical cables, which in turn trigger a smaller igniter charge.

2 Igniter charge

This consists of a small electrical heating element made from nichrome wire that glows hot enough to ignite a mixture of magnesium powder and potassium nitrate, triggering both the lift charge and the timed fuse.

3 Lift charge

A large part of the rocket's mass is the gunpowder that provides the upward thrust. This is usually 10 per cent sulphur and 15

per cent charcoal, with 75 per cent potassium nitrate to act as an oxidiser for the chemical reaction when the gunpowder burns. Commercial firework displays sometimes use sulphurless powder to reduce the smoke.

4 Clay nozzle

A plug at the bottom of the firework has a specially shaped aperture that channels the expanding gases from the lift charge to create thrust.

5 Timed fuse

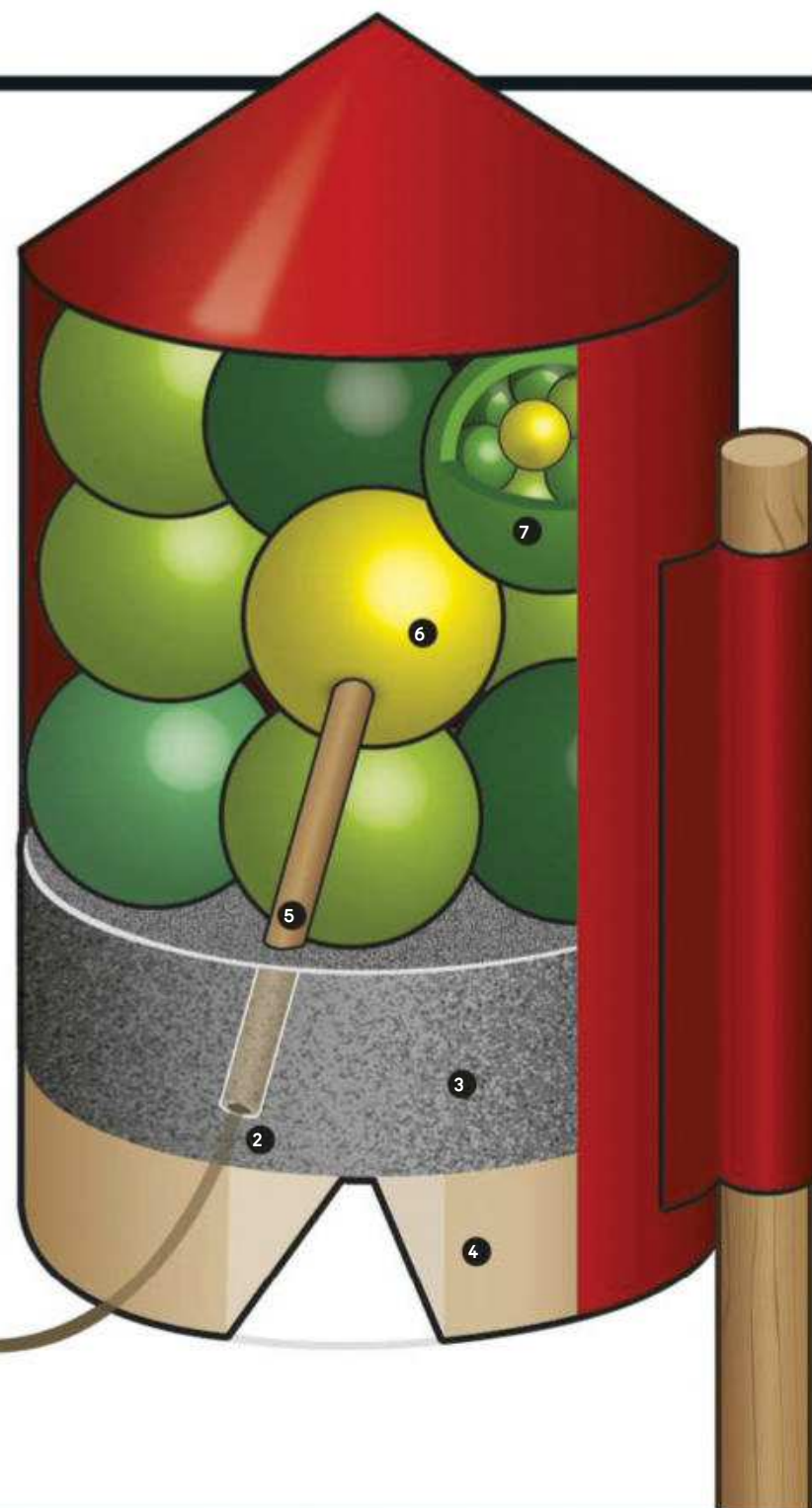
This hollow wooden tube packed with gunpowder is designed so that it burns through just as the firework reaches the top of its arc, setting off the main display burst.

6 Scatter charge

Another load of gunpowder is packed into a cardboard or plastic sphere in the centre of the firework. When the fuse reaches it, the explosion ruptures the firework's outer casing and flings the surrounding 'star' charges in all directions.

7 Star charges

These are pellets of different metal compounds which burn to produce the various colours and effects we see in the sky. For example, copper gives green patterns and strontium is used for red. The star charges may have their own smaller starbursts, fountains or pinwheels inside.



QUESTION OF THE MONTH

How far back in time would we be able to go and still breathe our planet's air?

DAVID KNOWLES, VIA EMAIL

Today, oxygen makes up roughly 21 per cent of our air, but it was virtually non-existent in Earth's early atmosphere. Soon after the advent of photosynthesis 2.4 billion years ago, oxygen levels crept up to 1 or 2 per cent – if you were to breathe this air, you would die almost immediately. Between 850 and 600 million years ago, oxygen concentrations increased steadily from 2 to about 10 per cent: still not enough for humans to survive on. Fast forward to 400 million years ago and you could just about breathe but might feel dizzy and confused on about 16 per cent oxygen. Around 300 million years ago, oxygen levels reached a human-friendly 19 per cent and have not dropped below since. **AFC**

WINNER!

David wins a Yeti Nano, worth £89.99, from Blue. The Yeti Nano is a premium USB microphone built for broadcast-quality podcasting, YouTube voiceovers, game streaming and Skype/VOIP calls and stands just 21cm tall. Find out more at bluedesigns.com



NEXT ISSUE:

Who was the first scientist?

How do parrots 'talk'?

Why does driving make me drowsy?

Email your questions to questions@sciencefocus.com or submit online at sciencefocus.com/qanda

OUT THERE

WHAT WE CAN'T WAIT TO DO THIS MONTH

NOVEMBER 2018

EDITED BY HELEN GLENNY

01

WILDLIFE PHOTOGRAPHER OF THE YEAR 2018

NATURAL HISTORY MUSEUM, LONDON
19 OCTOBER 2018 – SUMMER 2019

GO WILD

This 8cm-long firefly larva emits a continuous glow from four light organs at its rear, blazing a trail through leaf litter in Thailand's Peninsula Botanic Garden. The continuous glow is a warning to predators that the larva is unpalatable, while the flashing light of adult fireflies are intended to attract mates.

The image, which is highly commended at the Wildlife Photographer of the Year 2018 awards, was snapped by Christian Wappl. Wappl had to guess what direction the larva would travel in, then captured its journey with a 33-second exposure.

The winners of the competition will be announced on 16 October, and will go on display in London's Natural History Museum on 19 October.

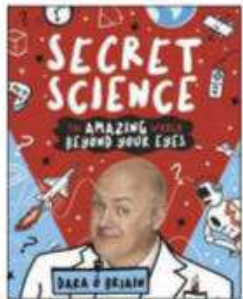
CHRISTIAN WAPPL/WILDLIFE PHOTOGRAPHER OF THE YEAR



02

HAVE A LAUGH

**SECRET SCIENCE:
THE AMAZING
WORLD BEYOND
YOUR EYES**
DARA Ó BRIAIN
OUT NOW
(£12.99, SCHOLASTIC)



Comedian and mathematician DARA Ó BRIAIN is diving into the invisible science behind everyday life in his second children's book, *Secret Science: The Amazing World Beyond Your Eyes*. He chats to HELEN GLENNY

What motivated you to start writing for children?

I knew that this would be an interesting group to write for because kids are naturally scientists. They ask questions, they're curious.

The ideal outcome is that when I'm sitting on a park bench feeding ducks in my later years, a woman in a white coat, literally in a lab coat, walks past and says 'Oh my god! I'm a scientist because I read

your books when I was a kid!' This is obviously a ridiculous leap. Why am I feeding ducks? Why is this woman still wearing her lab coat while walking in the park? There are so many things wrong with this fantasy but the general gist is that hopefully this stuff sticks with people.

What are the challenges of writing for children?

First of all, you've got to get stuff right. What you don't want to do is re-invent the *Brontosaurus*. I loved the *Brontosaurus* when I was a kid, didn't think about it for 15 years. Then I became a kids' TV presenter, and I said something about the *Brontosaurus* and my colleague told me nope, there's no *Brontosaurus*. It never existed. Someone put the wrong bone with the wrong hip, and we imagined a dinosaur that isn't there. Actually, there are now suggestions that it might be back, but it's been in and out at least once. Science moves on, and you don't want to be promoting half-remembered stuff.

Science has a reputation for being nerdy and boring – how do you tackle that?

Sure, there are parts of science where people are learning things and they won't understand why it's important until years later, and of course that's boring. But doing laps is boring, and playing the football match is fun.

This book is about the invisible things in everyday life: hormones, electrons, bacteria and forces, so we're covering loads of different stuff. In the first chapter, I say 'Listen, some of this stuff won't interest you. So skip it – there's another bit coming up which will be more your thing'. Then at the end I ask 'Okay, so which bits did you skip?' Because if you liked certain bits, you could become a neuroscientist, but if you liked other bits, you might be more into engineering.

Also, I don't believe the word nerd is an insult any more. It has been co-opted by too many people who don't deserve it. People say things like 'I like *Avengers*; *Infinity War*, therefore I'm a nerd.' No! You liked *Star Wars*? How unique.

I did four years of maths at university. I'm a nerd. You're not a nerd because you liked Luke Skywalker. That term is a badge of honour, more than anything else.

What's your favourite fact from the book?

I'm fond of the comparison that a giraffe sleeps for five minutes and a lion sleeps for 18 hours. If ever there's been a dividend for being a lion it's that you can sleep for 18 hours, whereas a giraffe grabs sleep for five minutes at a time.

Also, the air doesn't circulate in a plane. A plane takes in air through the engine and then sweeps the air out through a hole at the back of the plane. So when you fart, the fart doesn't stay in the plane.

FIND OUT MORE



Listen to our interview with Dara Ó Briain on the *Science Focus* podcast. Visit [sciencefocus.com/sciencefocuspodcast](https://www.sciencefocus.com/sciencefocuspodcast)





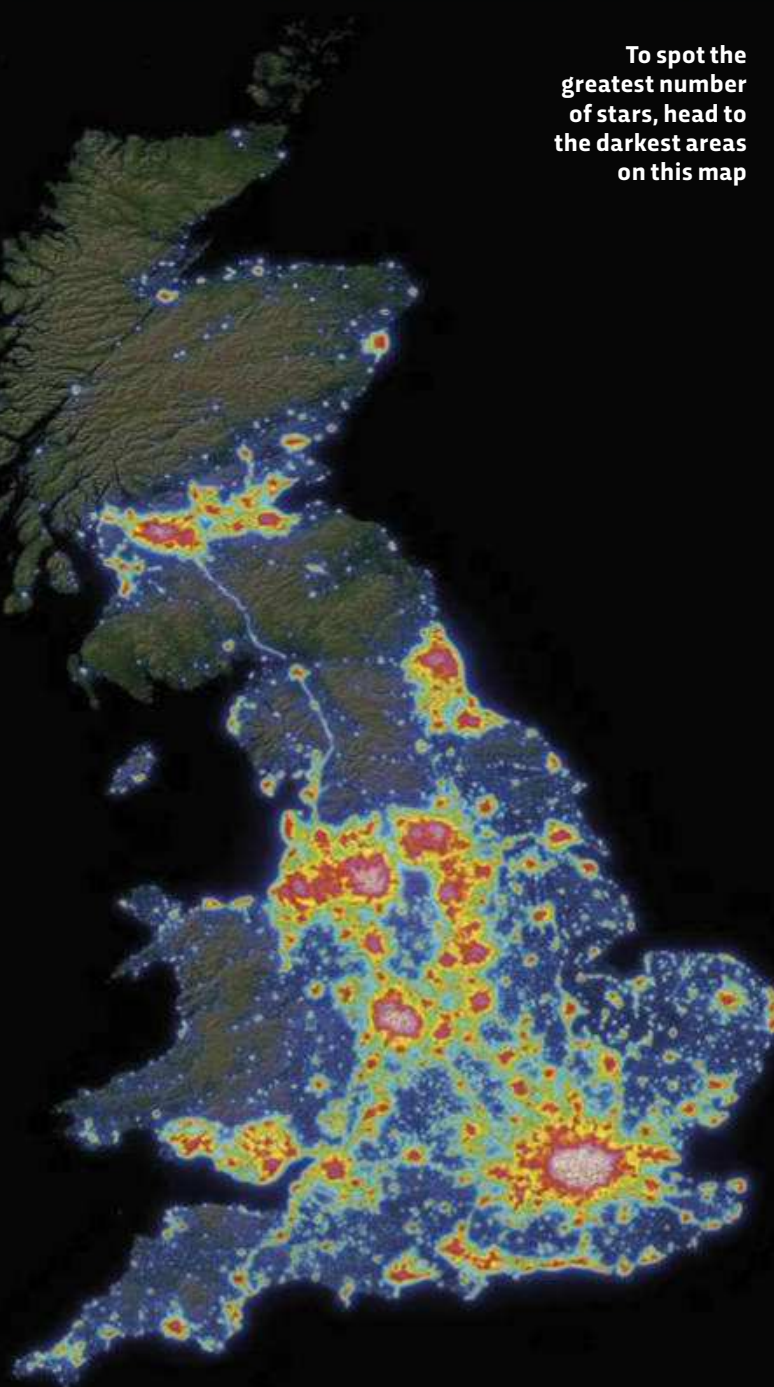
To spot the greatest number of stars, head to the darkest areas on this map

03

EXMOOR DARK SKIES FESTIVAL
EXMOOR NATIONAL PARK, SOMERSET
20 OCTOBER – 4 NOVEMBER 2018

STARGAZE

Head to Exmoor this October and November for the Dark Skies Festival. Starting on 17 October, it's 16 days packed full of astrophotography workshops, campouts, wild swimming and night walks. But if you can't make it to Exmoor, there are plenty of other spots to see the stars. Just head to the dark patches on this light pollution map, spread out a picnic blanket and let your eyes adjust. For full details, visit bit.ly/dark_sky_exmoor

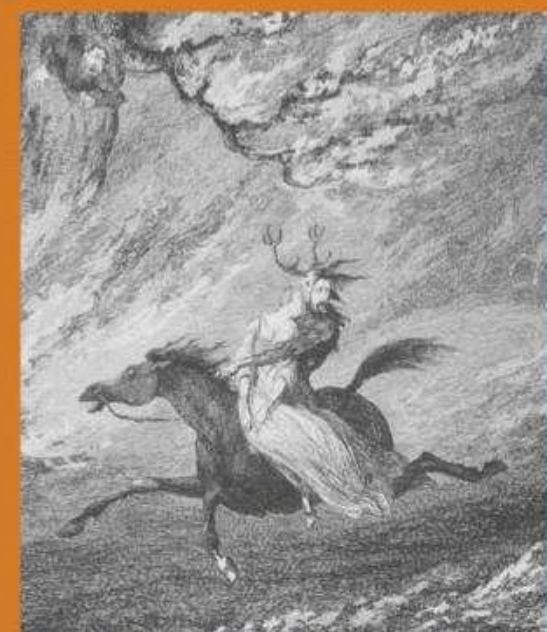


THREE THINGS TO SEE IN THE NIGHT SKY IN OCTOBER AND NOVEMBER...

ORIONID METEOR SHOWER

21-22 OCTOBER

This medium-strength meteor shower will peak on 21 and 22 October, producing around 20 meteors per hour. It'll be visible in both the northern and southern hemispheres, and is caused by dust from Halley's Comet.



HUNTER'S MOON

24 OCTOBER

The October full Moon might be named after Herne the Hunter, who in English folklore led Yell Hounds across the early winter sky. Another theory is that the Moon is now higher in the sky when full, giving more light for hunters to stalk their prey.

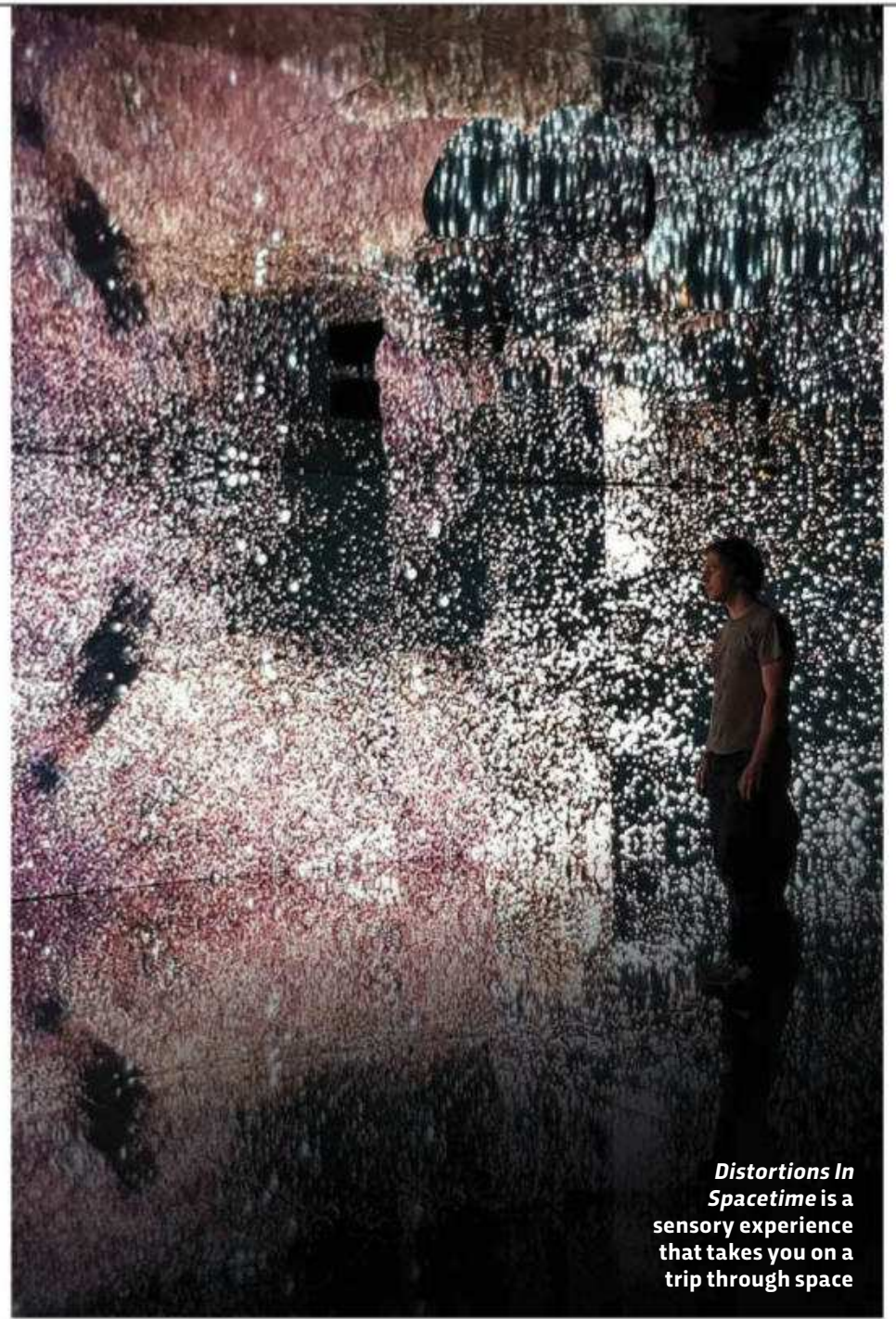
LEONIDS METEOR SHOWER

17-18 NOVEMBER

Some years, the Leonids meteor shower is one of the most dazzling, producing up to 1,000 meteors per hour. It won't reach those levels this year, but you'll still see some meteors radiating from the constellation Leo.

Visit bit.ly/SkyatNightMeteors for more information.

Manel Muñoz has upgraded himself so he can detect atmospheric changes via a sensor



Distortions In Spacetime is a sensory experience that takes you on a trip through space

04

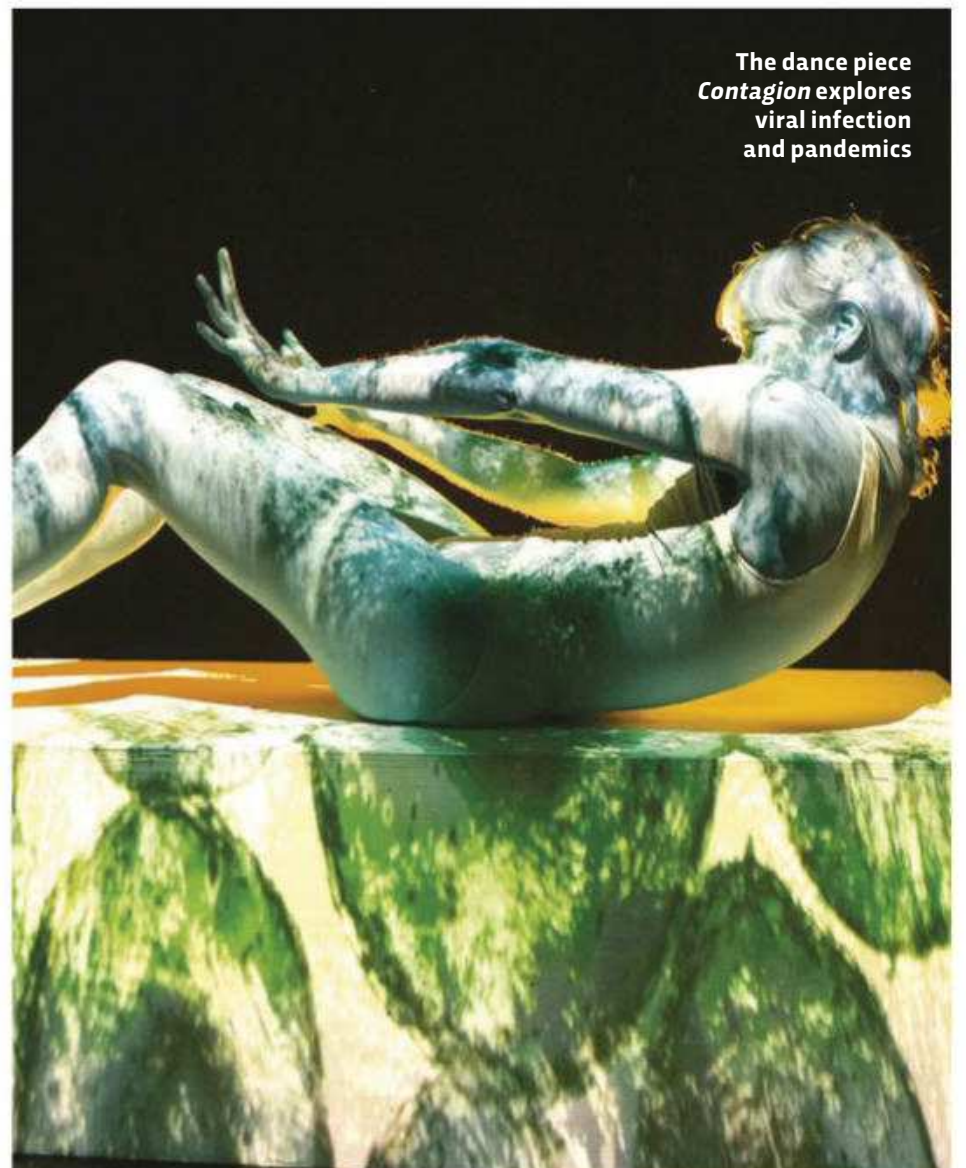
MANCHESTER SCIENCE FESTIVAL
18-28 OCTOBER
MANCHESTERSCIENCEFESTIVAL.COM

GET AN UPGRADE

This year's Manchester Science Festival is being headlined by a cyborg. Manel Muñoz can perceive the approach of cyclones and anticyclones via a barometric pressure sensor installed in his head. The sensor alerts him to the approaching weather patterns by transmitting beat frequencies through his skull. He's joining a cast of biohackers in a show called *You Have Been Upgraded* that explores human enhancement technology. It will be full of controversial conversations, with experts diving into the ethics around implants, and taking a deep look into how people are benefiting from the biohacking boom.

The Manchester Science Festival runs for 10 days with over 100 events taking place across Greater Manchester. You can bring origami amphibians to life using electricity, explore your own microbiome, or experience what it's like to be inside a black hole. Elsewhere, you can join conversations about reducing plastic pollution, the role of the face in identity and the power of the placebo effect.

The dance piece *Contagion* explores viral infection and pandemics



CHRIS NASH, BBC



Criminologist David Wilson (left) and actor Emilia Fox (right) are exploring the Jack the Ripper murders in a new BBC documentary

05

A MAN CALLED JACKBBC ONE
DATE TBC

SOLVE A COLD CASE

Criminologist DAVID WILSON and actor EMILIA FOX use modern scientific methods to re-examine the Jack the Ripper murders for a new BBC One science documentary. And thanks to these techniques, Wilson believes he's found the culprit. Here, he takes us through three of the methods he employed to solve this cold case

1. THE HOLMES COMPUTER

HOLMES stands for the Home Office Large Major Enquiry System, and it was set up by the police in the wake of the Yorkshire Ripper murders in the 1970s and 1980s. Police officers input the details of every violent crime that they investigate. Specific details might include the type of weapon that was used, where the body of the victim was found, or what sort of wounds the victim sustained. Over time, you can ask the filing system which other victims shared those same characteristics, and gradually you can interpret whether or not seemingly disparate events are connected.

2. GEOGRAPHIC PROFILING

A criminologist would use geographic profiling to investigate the pattern of where crimes have occurred in the hope of being able to establish whereabouts the killer might be based. It considers that crimes are less likely to occur further away from an offender's home base, that crimes occur in places that offenders and victims regularly visit, and that crime sites are not random, among other things.

3. ANATOMAGE TABLES

Anatamage tables allow us to explore injuries on the human body without the need to dissect a cadaver. It's a screen displaying the image of a woman who died about 10 years ago and gave her

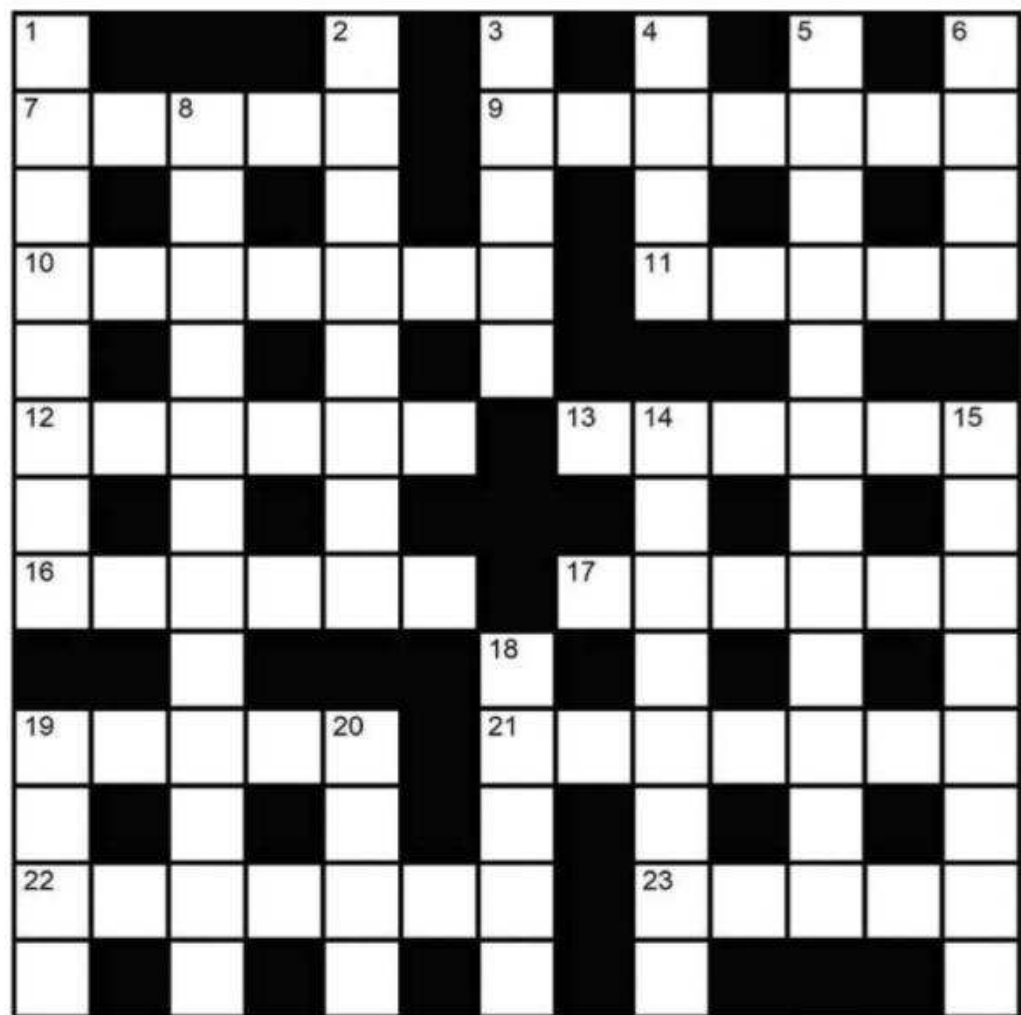
body to science. All parts of the woman's body, down to her organs, have been photographed millions of times. The table can take away the top layer of skin so you can examine the liver, the kidneys and so on. We were able to input all the injuries that the victims sustained onto an anatamage table so that we could really see what this killer was trying to do, and how what he was trying to do evolved over time.

FIND OUT MORE

Listen to our full interview with David Wilson on the *Science Focus* podcast. Visit [sciencefocus.com/sciencefocuspodcast](https://www.sciencefocus.com/sciencefocuspodcast)

BBC FOCUS CROSSWORD

GIVE YOUR BRAIN A WORKOUT



ACROSS

- 7 Fix metal stand, removing front (5)
- 9 Notes subject is in an abnormal place (7)
- 10 Answer – yours truly has changed into a bird or a reptile (7)
- 11 Bend over backwards to captivate European star (5)
- 12 Ruler has endless fruit (6)
- 13 When my organisation has left union protection (6)
- 16 Sleek arrangement acquires hard cash (6)
- 17 Ran off to elderly American traitor (6)
- 19 Caught sailor joining a Liberal clique (5)
- 21 Reading to rule out accepting shocking treatment (7)
- 22 Pole broken by weight of group of cyclists (7)
- 23 Queen's back to get a laxative (5)

DOWN

- 1 State a Republican has started another (8)
- 2 Make pale tea, brewed after energy and toil used (8)
- 3 Automobile veered around embankment (5)
- 4 Virile guy has way to turn damsel's head (4)
- 5 Article about plains first shows some backbone (6,6)
- 6 Second hired transport is for non-union man (4)
- 8 Bell leant crazily behind vehicle due to some radiation (3,5,4)
- 14 City in Sicily's borders wears a curse (8)
- 15 Evil dame flourished in the Middle Ages (8)
- 18 Nothing about time after loud rock (5)
- 19 Garment for Catholic primate (4)
- 20 Stringed instrument among wind instruments (4)

NASA X2, GETTY, TOKAMAK ENERGY

NEXT MONTH IN

FOCUS

MISSION TO MARS

WHAT THE INSIGHT CRAFT WILL DISCOVER ON THE RED PLANET



PLUS

The next space station



The hunt for Nessie



Nuclear renegades



ANSWERS

For the answers, visit bit.ly/BBCFocusCW
Please be aware the website address is case-sensitive.



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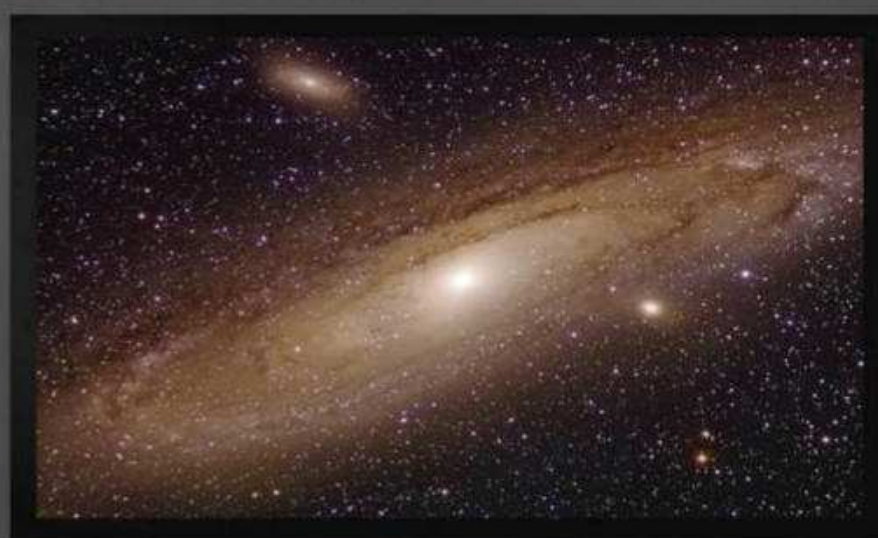
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MY LIFE SCIENTIFIC

Dr Cat Hobaiter

Chatting via Skype from a rainy Budongo Conservation Field Station in Uganda, **Cat Hobaiter** talks to **Helen Pilcher** about working with wild chimps

Cat's research camp in Uganda is comfortable. They live in wooden huts with a better Skype connection than in St Andrews!

What do you do?

I study apes in the wild. I'm interested in the gestures they make because it tells us something about how they think. I spend half my year living in the rainforest, trying to see patterns in their behaviour.

What's a normal day like?

I set my alarm for 5am because we have to catch the chimps as they get out of bed. I always start out really grumpy, then as the Sun slowly rises the forest comes to life. The colobus monkeys make this

amazing dawn chorus that ripples across the trees. It's beautiful. Somewhere in that 20 minutes, I fall back in love with what I do again. After that, it's all about hanging out with the chimps.

What do the chimps get up to?

Sometimes not much. They potter around and do a lot of sleeping. Sometimes it's pure chaos. When a big fig tree comes into fruit, maybe 50 chimps will come together and all hell breaks loose. Many people are interested in the drama of their lives, like when an alpha male takes over, but I love watching the

small stuff, like who sits next to who, or who's grooming who.

Worst thing about working with chimps?

Chimps kill other chimps. It's a normal feature of their society but you never get used to it. I once witnessed a male kill a female that I knew. They fought for hours and I just had to stand there and watch it. I remember filming it all while simultaneously balling my eyes out.

How many gestures do wild apes have?

Depending on the species, 70 to 80. It's a whole system of signals used to express meanings and desires. Everything from the big stuff, like who's going to get the girl, to the little stuff, like 'give me that food'.

Can you 'speak' chimp?

Sort of. One thing that struck me after spending so much time observing wild chimps is that I sometimes know what's about to happen before it happens. It's a really good feeling. I guess that means I can 'speak' a little chimp.

Do you try to communicate with them?

Never. I have a rough idea of what they mean but would never imitate them. I don't want them interacting with me, and I might not get it right. You don't want to say the wrong thing to a wild chimp!

Do chimps have regional accents?

That's the million dollar question. West African chimps have a couple of gestures we don't see in East Africa. We're working on this now.

What keeps you awake at night?

The tree hyraxes. They're like fat guinea pigs and they make a sound like someone being murdered. My nemesis is a hammerhead bat who lives in the mango tree outside my room. He makes an annoying 'pinging' noise and will only shut up if I shine my torch at him! 🦇

Dr Cat Hobaiter is a primatologist at St Andrews University.

DISCOVER MORE

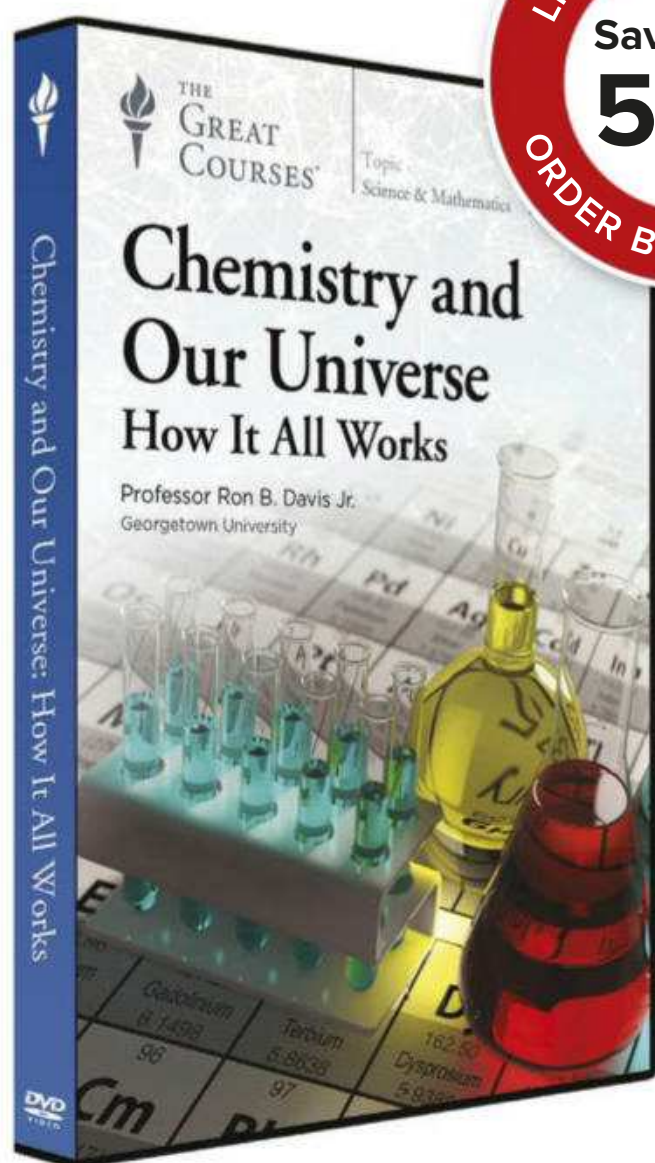


To listen to an episode of *The Life Scientific* with Cat Hobaiter, visit bit.ly/cat_hobaiter

NEXT ISSUE: DR SUE BLACK

ILLUSTRATION: ALEXANDER WELLS

"CHIMPS KILL OTHER CHIMPS. IT'S A NORMAL FEATURE OF THEIR SOCIETY BUT YOU NEVER GET USED TO IT"



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LECTURE TITLES

1. Is Chemistry the Science of Everything?
2. Matter and Measurement
3. Wave Nature of Light
4. Particle Nature of Light
5. Basic Structure of the Atom
6. Electronic Structure of the Atom
7. Periodic Trends: Navigating the Table
8. Compounds and Chemical Formulas
9. Joining Atoms: The Chemical Bond
10. Mapping Molecules: Lewis Structures
11. VSEPR Theory and Molecular Geometry
12. Hybridization of Orbitals
13. Molecular Orbital Theory
14. Communicating Chemical Reactions
15. Chemical Accounting: Stoichiometry
16. Enthalpy and Calorimetry
17. Hess's Law and Heats of Formation
18. Entropy: The Role of Randomness
19. Influence of Free Energy
20. Intermolecular Forces
21. Phase Changes in Matter
22. Behavior of Gases: Gas Laws
23. Kinetic Molecular Theory
24. Liquids and Their Properties
25. Metals and Ionic Solids
26. Covalent Solids
27. Mixing It Up: Solutions
28. Solubility and Saturation
29. Colligative Properties of Solutions
30. Modeling Reaction Rates
31. Temperature and Reaction Rates
32. Reaction Mechanisms and Catalysis
33. The Back and Forth of Equilibrium
34. Manipulating Chemical Equilibrium
35. Acids, Bases, and the pH Scale
36. Weak Acids and Bases
37. Acid-Base Reactions and Buffers
38. Polyprotic Acids
39. Structural Basis for Acidity
40. Electron Exchange: Redox Reactions
41. Electromotive Force and Free Energy
42. Storing Electrical Potential: Batteries
43. Nuclear Chemistry and Radiation
44. Binding Energy and the Mass Defect
45. Breaking Things Down: Nuclear Fission
46. Building Things Up: Nuclear Fusion
47. Introduction to Organic Chemistry
48. Heteroatoms and Functional Groups
49. Reactions in Organic Chemistry
50. Synthetic Polymers
51. Biological Polymers
52. Medicinal Chemistry
53. Poisons, Toxins, and Venoms
54. Chemical Weapons
55. Tapping Chemical Energy: Fuels
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